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Much of this booklet is excerpted from the air chapter of the *Green Toolbox: A Curriculum Focusing on Virginia's Sixth Grade Science Resources Strand 6.9.* The toolbox is designed to help students understand scientific and economic principles governing the sustainable management of Virginia's natural resources.

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Virginia Cooperative Extension
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Science Museum of Virginia
Chesapeake Bay Foundation

Air Resources

An introduction to air resources in Virginia from the Virginia Natural Resources Education Guide, http://www.vanaturally.com/guide.html

Look up in the sky. Air seems boundless and for that reason, it is a resource often taken for granted. Above the state of Virginia alone rests over one trillion tons of it. But, just like water, not all of it is usable to you. Yet even with all of this volume, air must constantly be reused. In fact, the air you are breathing now was in someone else's lungs earlier. Air is the ultimate recyclable material!

Question:

Since oxygen is always being used to burn food into water and carbon dioxide, why doesn't it all get used up?

Answer:

Photosynthesis. Green plants use light and carbon dioxide to produce glucose and oxygen. The use and reuse of oxygen is called the oxygen cycle.

Air is a mixture of invisible and odorless gases, mostly nitrogen and some oxygen. Water droplets, fine particles, and small amounts of other gases such as carbon dioxide, methane, ammonia, and argon are also part of the mix. If air is clean, we can neither see it, taste it, nor smell it.

What is Air Pollution?

Often what we can see or smell in the air is air pollution. Air pollution is any visible or invisible particle or gas found in the air that is not part of its normal composition. Some substances are so common and widespread, they build up in the air and become a hazard to human health.

The U.S. Environmental Protection Agency has developed health-based national air quality standards for six pollutants. They are: carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. In addition to these six criteria pollutants, standards have been set for over 120 toxic air pollutants (hazardous chemicals found in the air which are known or are suspected to cause cancer, genetic mutations, birth defects, or other serious illnesses in people even at low exposure levels). These contaminants include arsenic, benzene, beryllium, mercury, vinyl chloride, and radionuclides. Companies that produce such pollutants are required to use special equipment to control how much is emitted into the atmosphere.

Where Does Air Pollution Come From?

Air pollutants have occurred naturally since the earth's formation. Particulate matter and gases are emitted from every corner of the globe: from volcanoes, tree pollen, forest fires, and decaying organic matter in oceans and wetlands.

Much air pollution, however, results from human activities – from burning coal, oil, wood, gasoline, and other fuels used to run factories, cars, farm and off-road vehicles, and construction equipment, and from power plants that generate heat and light for our homes and businesses. Burning these fuels produces smoke and gases. Smoke is made of tiny particles of soot and ash suspended in the air called "particulate" matter. Sawdust from lumber mills, rock dust from quarries, and soil particles from bare earth are other examples of man-made particulates found in the air.

Once particulates are added to the air, they can chemically react to form pollutants that are even more dangerous. For example, when nitrogen oxides and chlorine interact with hydrocarbons in the presence of sunlight, ozone is formed. When it is formed at ground level, it acts as a powerful respiratory irritant that makes it hard for people to breathe, can damage lung tissue, and make respiratory ailments worse. High levels of ozone – which means over 0.12 parts per million in an hour or over 0.08 ppm over eight hours –, are frequently found in urban areas during hot summer months. When this happens, you are likely to hear a "Code Red Ozone Alert." Reading almost as high may cause an "air quality advisory" or Code Orange Alert. Though very infrequent, there have been Code Purple Ozone Alerts which are more severe than Code Red.

This is in sharp contrast to the ozone you may be most familiar with. That ozone, which exists in a layer found in the upper atmosphere (or stratosphere), provides a protective barrier against harmful radiation from the sun.

Just What is Ozone?

Ground-level ozone, the main ingredient of smog, is a colorless gas formed by the reaction of sunlight with vehicle emissions, gasoline fumes, solvent vapors, and power plant and industrial emissions. Ozone formation is most likely in hot, dry weather when the air is fairly still. Ozone pollution is one of the most serious problems in Virginia's urban areas. Symptoms felt include shortness of breath, chest pain when inhaling deeply, wheezing, and coughing. Children, people with respiratory disease, and individuals who exercise outdoors are at particular risk from high ozone levels. It can make these problems worse, send people to the hospital and can even damage lung tissue.

Always On the Move

Pollutants of any sort can ride the air currents for long distances. Some of Virginia's pollution is carried in from sources in the Midwest, especially large coal-fired power plants. Air can "cleanse" itself to some degree by such processes as rain; otherwise dense, poisonous clouds would already cover the earth. Sometimes the weather does not permit this cleansing to happen, and the air stagnates due to a weather condition known as an inversion.

Normally, as you go higher up in the air, the temperature gets colder. Hot polluted gas from cars or smoke-stacks rises through the cooler air above and blows away. Sometimes a layer of warm air forms above the cooler air below (often in a valley like Roanoke or Charlottesville). When this inversion happens, the polluted air will rise up to the warm layer and then stop. In this way, a giant cloud of pollution can form over a community.

While the air may be cleansed after a good rain, many of the chemicals and small particles washed from the atmosphere become land or water pollution. In fact, scientists have estimated that as much as 25-30 percent of the nitrogen pollution in the Chesapeake Bay is a result of acid deposition. While "normal" rainfall has a pH of about 5.5, precipitation in Virginia can be up to ten times more acidic, ranging from 4.3 to 4.5.

What Are the Effects of Air Pollution?

Air pollution is dirty and it is expensive. More important, polluted air can make healthy people cough and wheeze. For people who are sick or especially sensitive, air pollution may worsen an existing condition and mean discomfort, limited activities, increased use of medication, and more visits to doctors and hospitals. A growing body of scientific studies suggests that air pollution has long-term effects on the lung's ability to function and contributes to the development of lung disease.

Our noses and sinuses have a built-in filtration system that traps large dust particles before they get into our lungs. And human lungs have a natural defense system that helps to protect us against some of the air pollutants breathed. But people respond differently to air pollution and very small particles are not filtered out. How people respond, or their level of risk, depends on several factors, including the amount of pollution in the air, the amount of air breathed in a given time, and their age and overall health.

Just What is Acid Rain?

"Acid rain" is really rain, snow, or fog that contains sulfuric or nitric acid. Acid rain, or "deposition," forms when water vapor mixes with sulfur and nitrogen oxides. Sulfur and nitrogen come from natural sources like volcanoes, but are common by-products of the combustion of fossil fuels (coal and petroleum), which are burned principally to heat homes and generate electrical power. Sulfur dioxide and nitrogen oxides released during burning usually travel many miles before falling to the ground as acid rain. PH is measured on a scale ranging from 0, which is severely acidic, to 14, which is extremely basic. A value of 7 is neutral. Lemon juice has a pH of 2; baking soda, 8; a cola drink, 4; and pristine rain is about 5.6. Natural precipitation is about ten times less acidic than the average value of rainfall in Virginia – 4.3 (extremely acid). However, pH can vary from week to week (and rainstorm to rainstorm) from 3.5 to 5.0. Acid deposition levels in Virginia are comparable to other areas of the mid-Atlantic and Northeast regions of the U.S.

Effects of Acid Rain

Sulfuric acid in the air can hurt the lungs of infants, children, and adults. It can contaminate drinking water by dissolving minerals from soil and pipes which are then carried into the water supply. Acid rain has been blamed for damaging trees and mountain streams in Virginia and the northeastern United States. High acidity levels can kill new fish eggs. Airborne nitrogen oxide is also believed to be responsible for an estimated 30 percent of the nitrogen pollution entering the Chesapeake Bay. Excessive nitrogen and other nutrients in the Bay overstimulate algae growth, thereby reducing the oxygen levels available for other plants and fish.

Scientific studies performed in the early '90s confirm that initial estimates of the national damage caused by acid rain were overstated. However, central Appalachian region ecosystems are severely stressed by acid deposition due to the low neutralizing capacity of local soils. The physical and chemical properties of these soils are such that they cannot buffer, or offset, the acid. This region of the state unfortunately receives a high rate of deposition of sulfur compounds from power plants in the Midwest.

What Can Be Done?

Managing air is a complex undertaking because it is a substance constantly on the move. Air is affected by sunlight, dust particles, water vapor, and wind currents-factors which by their very nature are also moving.

When it comes to air pollution, technology has served as both a culprit and a cure. Devices used to control pollution from smokestacks and exhaust vents include:

- The cyclone – a system where heavy dust is spun right out of the air.
- The electrostatic precipitator – which uses static electricity to attract dust particles, in the same way that a comb picks up bits of paper after being charged with static electricity by your hair.
- The scrubber – which uses a water spray to wash dust and gases from the air.
- The filter system/bag house – which works like a vacuum cleaner bag to collect dust.

Some emissions are pre-treated before being released. For example, some power plants spray a limestone slurry (a mixture of limestone and water) to neutralize the acid resulting from burning coal. Catalytic converters that help decrease emissions from automobiles are another example.

Of all the types of pollution, odors are probably the hardest to control because we can smell even tiny amounts of so many substances. (The nose is a great piece of monitoring equipment!) A new technology called biofilters actually uses bacteria to "eat" odors.

What Are Those in Government Doing About Air Pollution?

The U.S. Congress passed important federal air pollution laws, known collectively as the Clean Air Act (1963; and amended in 1967, 1970, 1977, and 1990). National air quality standards spelled out how clean the outdoor air has to be, and it is up to each state to see that its air meets these standards.

In 1966, the Virginia General Assembly passed the Virginia Air Pollution Control Law. The regulations are administered and enforced by the Department of Environmental Quality.

Some of the goals of the new Clean Air Act Amendments are listed here:

- Reduce hazardous pollutant emissions within 10 years.
- Decrease urban smog by reducing emissions from small businesses as well as large factories and vehicles.
- Reduce emissions from electric utilities in two stages by the year 2000: ten million tons of sulfur dioxide, and two million tons of nitrogen oxide.
- Both new and existing sources of toxic pollutants that are identified as subject to Maximum Achievable Control Technology (MACT) will be expected to reduce emissions by 90% or more.

In Virginia, the Department of Environmental Quality works closely with the U.S. Environmental Protection Agency to monitor and evaluate hazardous air pollutants across the state. A computer model that estimates concentrations of 185 hazardous air pollutants statewide helps pinpoint regions of most concern. Data is

collected every three years and added to the model and allows better evaluation of the state's air pollution strategies.

Virginia is working to achieve the requirements of the 1990 Clean Air Act, a federal law amended by Congress. One provision, Title IV, calls for reductions of sulfur dioxide of approximately ten million tons per year and two million tons of nitrogen oxides per year. Virginia's power plants are preparing to take steps necessary to reduce nitrogen oxides. Most of the reductions in pollutants will occur at large coal-fired power plants in the Midwest. Some of these individual plants emit more than all the sources in Virginia combined. Emissions from these large plants are released from very tall smokestacks and travel eastward, sometimes hundreds of miles, before returning to Earth in precipitation or dust. In 2005 EPA issued the Clean Air Interstate Rule (CAIR) which targets reducing emissions of sulfur dioxide and nitrogen oxides from power plants in 28 states and the District of Columbia. Virginia is actively working to achieve these emission reductions.

Prevention is Key

Like so many other forms of pollution, the surest solution to air pollution is prevention. This means many things. It means wise transportation and community planning. It means adopting new processes and materials for industrial operators. It means each person doing their share by conserving the resources they use, particularly electricity and gasoline.

Additional Resources

Websites:

- VA Department of Environmental Quality – http://www.deq.virginia.gov
- National Oceanic & Atmospheric Administration – http://www.noaa.gov/
- Wolverton Environmental Services – http://www.wolvertonenvironmental.com/
- US Environmental Protection Agency, Office of Air & Radiation – http://www.epa.gov/oar/
- National Acid Precipitation Program – http://www.oar.noaa.gov/organization/napap.html
- The Plants for Clean Air Council, 10210 Bald Hill Rd., Mitchellville, MD 20721
- Air & Waste Management Association – http://www.awma.org/

Fundamental Learnings Related to Air

- Air is one of the physical or abiotic (nonliving) factors that influence living organisms.
- There are two main types of air pollutants: primary and secondary. Primary pollutants are those emitted directly into the air, such as smoke and chemicals (particulates, oxides of nitrogen hydrocarbons, sulfur dioxide, and carbon monoxide). Secondary pollutants are produced from the chemical interactions of primary pollutants with other atmospheric compounds. Examples are smog, acid rain, and ozone.
- Particulates are small particles such as dust or soot that contribute to air pollution. Natural processes such as forest fires and volcanic eruptions, as well as man-made processes such as burning coal or oil (fossil fuel), release air pollutants.
- Burning fossil fuels emits chemical by-products. These combine with moisture in the atmosphere to form acids, which fall as acid precipitation (rain or snow).
- Air pollution affects the health of lakes, forests, wildlife, crops, water supplies, and humans.
- Ozone in the air we breathe damages our health while ozone in the upper atmosphere protects us from harmful radiation.

Window on Air Quality

A unit from Green Toolbox – focused on environmental management including costs and benefits, particularly useful for teaching science standard 6.9.

Introduction

Balancing the goal of good air quality with maintaining the conveniences of modern life is a challenge requiring conservation and government policy. Students will learn about the effects of transportation, manufacturing, and consumption on air quality, know some of the policy alternatives, be able to discuss their costs and benefits, and seek ways to minimize their own impact on air quality. At each step have students describe how energy may be wasted.

Standards of Learning

Science 6.1, 6.2, 6.4, 6.6, 6.9
Math 6.8, 6.10, 6.12

Objectives

In these lessons students will:

- Identify the primary sources of air pollution in Virginia
- Identify the costs of air pollution
- Discuss preventive measures to protect air quality
- Identify and discuss cost/benefit tradeoffs of policies to improve air quality

Key Terms/Concepts

- Air pollution
- Particulates
- Smog
- Property rights
- Acid rain
- Fossil fuel
- Subsidize

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VMA OUTREACH
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Student Information – Air

While water is essential to the survival of humans and animals alike, we are even more limited in the duration of time we can survive without breathing in oxygen from the air. It is unsafe for us to go without air for little more than a minute.

Even if you are above water and able to inhale air, its quality is of major importance and can affect your health. Nitrogen, oxygen, and carbon dioxide are three major components found in air. Any component that is not found naturally in air is known as a pollutant. Small amounts may not be harmful to you. Dust, sulfur dioxide, methane and carbon monoxide are examples. These and other components may be attributed to causing smog, acid rain, retarded plant growth, and respiratory conditions.

In order to protect our environment and health, several measures may be taken to reduce air pollution. Did you know conserving energy is the best thing you can do to reduce air pollution? The burning of fossil fuels to make energy produces byproducts which can harm the environment. We can reduce pollution by using less energy around school and your home. Another way is by driving less. By using public transportation or walking you reduce the amount of emissions produced from individual cars. Can you think of other ways to reduce pollution or clean up the air that has already been polluted? What effects might air pollution have on the quality of water in your area?

Background Information for Teachers

Defining Air Pollution

Air pollution includes any particles or gases that are not part of the air's natural composition. Air is mostly composed of nitrogen, with a smaller amount of oxygen. Small amounts of carbon dioxide, methane, ammonia, and argon also occur naturally in the air.

Air pollution can be generated either by natural or human activities. For example, volcanic eruptions, forest fires, and trees (pollen) all emit some form of air pollution. The forests in the Blue Ridge Mountains release a natural emission that causes the blue color of the range (Peirce, Weiner, and Vesilind 1998). While this air is not pure, the air pollution with the greatest environmental and health hazards is produced by human activities, and includes emissions from cars, farm equipment, industrial activities, and power plants. Cars and industry powered by burning coal, oil, wood, or gasoline release smoke and other gases into the air.

Identifying Pollutants

Several pollutants such as smog, acid rain, heavy metals, and particulates, affect our environment and our lives.

Smog: When someone says the word "ozone," we usually think of the layer in the upper atmosphere that protects the Earth from harmful solar radiation. However, ozone is a chemical (O3) forms in the lower atmosphere on hot, sunny days when nitrogen oxides react in the atmosphere with hydrocarbons from cars, power plants, and industrial emissions. Ozone is also the main ingredient in **smog,** a mixture of pollutants in the air that reduces visibility and can have harmful effects on human health and the environment. For smog to develop in the air, pollutants must "cook" in the sun. By the time the smog is done, it may have been blown far from the original source of the pollutants.

Volatile Organic Compounds (VOCs), including hydrocarbons, are another major contributor to smog. Some VOCs, released from car emissions, are linked to cancer.

The burning of **fossil fuels** such as oil, coal, and natural gas, results in other air pollutants as well. One is carbon monoxide, an odorless compound that can impede the delivery of oxygen to cells. While for health and environmental reasons it is wise for us to reduce the quantity of pollutants produced from fossil fuels, there is another reason for us to conserve. Fossil fuels are a non-renewable resource, which means no new oil or coal will form during our lifetimes. Developing technology for renewable sources of energy such as wind or solar power (we will not run out of sun or wind) would reduce the drain on the resources we cannot replace, while cutting down on the pollution formed by fossil fuels.

Acid rain: Sulfur dioxide and nitrogen oxides released into the air are primary causes of acid rain. These emissions may also travel from coal-burning plants in states in the Midwest. Sulfur dioxide reacts with water in the air and creates sulfuric acid that then falls to the Earth in the form of snow or rain. To be considered acid rain, precipitation must have a pH lower than 5. Pure water has a pH of 7.0. Normal rain that has not been affected by sulfur dioxide is slightly acidic because carbon dioxide dissolves into it, so it has a pH of about 5.5. As of the year 2000, the most acidic rain falling in the US has a pH of about 4.3. (Bodnar). *Activity 2* tests the acidity of rainwater.

Sulfur is found in the coal, and when burned, mixes with oxygen to create the sulfur dioxide. The other major cause of acid rain, nitrogen oxides, is created through the burning of any fossil fuel, including natural gas and oil. Nitrogen oxides are released into the air through the exhaust of most vehicles, making car emissions the primary source of nitrogen oxides. When weather conditions are right, these acids return to the earth in the form of rain, snow, fog, or mist, sometimes far away from where the chemicals were produced.

Air pollution control equipment: Significant improvements have been developed and utilized in sophisticated technology for pollution abatement. Power plants today have invested in scrubbers, baghouses, and/or precipitators that have dramatically reduced emissions.

Heavy metals are another form of air pollution. Lead and mercury are two examples of this kind of pollution, which can result in organ damage in humans, including brain damage, and can also harm wildlife. These metals can enter the air through the use of leaded gasoline, lead paint, metal refining, combustion of fossil fuels, and manufacture of lead or mercury batteries.

Particulates: Besides specific chemical compounds, particulate matter in the air also poses a problem. Particulate matter, consisting of little particles of dust and soot, can be a cause of haze. It is sometimes responsible for bronchitis and lung damage. Particulates may enter the air through the burning of fossil fuels, but may also occur through burning wood. *Activity 3* measures the particulate matter in your area.

Costs of Pollution

Air pollution imposes costs on human health, property, and the environment. Ozone has the potential to intensify respiratory ailments, make people cough or wheeze, and damage lung tissue. Children, asthmatics, and the elderly are particularly at risk.

Humans are not the only creatures harmed by air pollution, however. Ozone retards the growth of many plant species. Acid rain reduces aquatic animal populations: many species of trout, bass, and clams are unable to survive in water polluted by acid rain. Acid rain can also dissolve limestone and marble in buildings and statues. *Activity 4* gives an example of how acids can damage structures.

Mercury Mystery . . . ???

Dragon Run, one of Virginia's most pristine natural areas, contains some amounts of mercury – a highly toxic metal, sometimes found in fish tissue. How did it get there? Not naturally found in the Dragon Run Watershed, mercury must come from an external source. Since Dragon Run has experienced little human impact, some scientists are wondering about the origin of this metal pollutant. One theory focuses on atmospheric deposition, of mercury, from industrial sources.

What do you think? Help scientists solve the mystery. For more information see the following site: www.deq.virginia.gov/fishtissue/pdf/vahg42004.pdf

Preventive Measures to Decrease Air Pollution

Air pollution can damage human health and the environment, but there are steps we can take to minimize its effects. While government agencies and industry may have different incentives to regulate and reduce air pollution, people in the community also have an interest in cleaner air. So how can we improve air quality in our community, make wise decisions about health and the environment, and influence other people such as parents and friends to do the same? *Activity 5* offers some ideas on how to conserve at home, thereby reducing the output of two major sources of pollution: energy production and vehicle emissions.

Virginians drive their cars more each year; plus, as population increases in Virginia, there are more drivers. Loudoun County is the third fastest growing county in the nation, and Northern Virginia, Hampton Roads, and Richmond areas are also growing particularly fast. According to the Metropolitan Washington Council of Governments, the Virginia "outer suburbs" of Washington, D.C. will grow three times faster than the rest of the region over the next decade, which means many people may live far from where they work. More public transport is now offered, but more planning will be required to keep up with the growing needs of the community. Most new vehicles have emission control devices of varying efficiency. In the meantime, we can choose to walk, bicycle, take public transport when possible, and/or install pollution abatement equipment on older vehicles.

Conserving energy is another way to limit air pollution by lessening the amount of fossil fuel that needs to be burned to provide our heat and electricity at home. Turning off lights and appliances when we are not

using them, using heat and air-conditioning with care, insulating our homes, and limiting fires are a few places to start.

Policy Options to Decrease Air Pollution

The task of state governments in regulating air pollution is a difficult one. First, air pollution can travel long distances, affecting residents of states far from where the pollution was first produced. For more details or the daily air quality report, visit www.deq.virginia.gov or view the Department of Environmental Quality's power point slide show about air quality management. Another problem lies in assigning property rights, or deciding who owns the right to produce pollutants, or who has the right to an unobstructed view of a clear skyline. For more explanation of property rights, see *Activity 6*.

While we can all help to lessen air pollution by practicing conservation at home, often the government also needs to get involved in reducing it. Government has several options:

1. It can pass laws that ban or limit the quantity of pollution that power plants or other industry can produce, and punish companies that produce more than the legal limit. This is called a command and control approach.
2. Tax fossil fuels, making it more expensive to produce pollution.
3. Subsidize energy-efficient equipment and appliances, by giving tax breaks or rebates to companies or consumers who choose to buy them.
4. Issue allowances to each polluter, giving them permission to produce a certain amount of pollution. There are advantages to each of these choices.

Bans and Limits – the Command and Control Approach

Suppose that the government decided that there should be zero sulfur dioxide pollution. All companies producing sulfur dioxide emissions, including power plants fired by coal, would not be allowed to operate by the government. There are benefits: first, there would be no more sulfur dioxide emitted, which would greatly reduce acid rain. Second, this would reduce the use of coal, which is a non-renewable resource. What are the costs? Many people depend on these power plants for electricity, and without their electricity, they could not use their lights, televisions, computers, or washing machines. Imagine if things such as hospital equipment and ATMs had to be turned off. While there are costs to having sulfur dioxide in the air, there are also important benefits to having electricity available.

For another example, imagine that the government decided to reduce the amount of ozone in the air. Since much of ozone comes from vehicles, each car can only be driven every other day. Cars with odd-numbered license plates could be used on odd-numbered days, and cars with even-numbered license plates would be driven on even-numbered days. If people follow the rules, there will be less emissions and ozone. Because cars are driven fewer miles, less gasoline, which is a non-renewable resource, will also be used. What else would happen if people could only drive cars every other day? Some people would take public transportation when they could not drive their cars. Some people would buy another car so that they could drive every day, which would defeat the purpose of the legislation. Some people would lose their jobs because they could not get to work. Some people would probably try to get around the regulations, and the government would have to spend a lot of time and money enforcing them. The government's policy of telling people on which days they may drive has significant costs for the citizens, both to their convenience and their tax dollars.

Rather than ordering companies not to pollute, the government might command them to invest in technologies that reduce their pollution output. While implementing this policy will reduce pollution, it also has high costs. For some of the cleaner facilities, investing in new technology might be very expensive, and only reduce their pollution by a small amount, i.e., the costs outweigh the benefits. Government also will have to spend money to enforce this law, monitoring the progress of each of the plants involved (Ellerbrock). For a demonstration of a basic technology to reduce air pollution, see *Activity 7*.

Taxes and Subsidies Another way government can influence the quantity of pollution is through the use of taxes or subsidies. Government might tax plants for the amount of pollution they produce, or tax consumers in a way that causes them to use less energy. Imagine if there were a tax on electricity that doubled the electricity bill in your house each month. How might your family react? Since each kilowatt-hour costs twice as much as before, you will probably be more careful about turning off lights when you are not home, and unplugging appliances you are not using. If everyone has to pay more for their electricity, most people will probably reduce their consumption of it. Instead of turning up electric heat, they might wear a sweater or use a wool blanket; instead of leaving the lights on when they go out, they will be sure to turn them off. Because less electricity would be needed, fewer fossil fuels would be burned, and less pollution would be created, along with fewer jobs in the power industry. Government would not have to send someone to make sure you use less electricity. See *Activity 8* for another illustration of the power of taxes to decrease pollution.

Besides using taxes to encourage conservation, government can promote better environmental practices through subsidies, or grants of money. For example, a power plant might consider upgrading its facility, which would make its production cleaner and more efficient. Government might offer an incentive by paying for part of the upgrade. In the home, air conditioners are often the biggest users of electricity. By offering rebates to consumers who buy the more expensive, but more energy-efficient models, the total amount of electricity used would decrease, thus decreasing the amount of pollution it causes.

Pollution Allowances A third option government could choose to reduce pollution is to issue pollution allowances which give companies permission to release a certain amount of pollution during a year. Government first decides what the total amount of a particular pollutant companies in a region are allowed to release and creates pollution allowances.

Companies must obtain enough pollution allowances to cover the amount of pollution they release into the environment. The government may chose to auction the pollution allowances to companies that want to operate. The total number of pollution allowances auctioned equals the amount of pollution the government had decided it will allow to be released into the environment. All the firms operating in that area must then "buy" the right to continue polluting by purchasing pollution allowances. Most companies will buy pollution allowances, while some of the highest-polluting companies may decide to close down because it would be too expensive to buy enough pollution allowances to cover their pollution. Once companies own these pollution allowances, they can also trade them. For example, if one company wants to open a new plant, it would have to buy pollution allowances from another company. A company that decides to upgrade its plant, and make production cleaner or more efficient, would be able to sell some of its pollution allowances. It is in the firms' interest to operate more efficiently and cleanly so that they need to own fewer pollution allowances. At the same time, these companies make their own decisions about how best to reduce their pollution, based on their individual situations, thereby rewarding good management and corporate flexibility (Ellerbrock). For a demonstration of assigning property rights, see *Activity 6*. For more discussion on distributing pollution allowances, see *Activity 9* and the powerpoint show from DEQ.

Activity 1A *Visualizing Air Pollution: Code Red for the Shenandoah Mountains*

Related Standards of Learning: Science: 6.6, 6.7, 6.9

Objectives: The student will:

- observe the differences in the combined photograph of Shenandoah National Park taken on different days from the same location.
- describe the differences in the photograph using the terms haze, visibility, and humidity and particles

Materials Needed:

- Computers with internet access

Procedure:

1. Display the photograph of the Shenandoah National Park from the website:
   http://www.nps.gov/shen/pphtml/subenvironmentalfactors23.html
   This photograph was taken in the Shenandoah National Park on two different days. The two photographs were combined into one to show the difference in a clear day and a hazy day. The photograph may be enlarged to show detail.

2. Research the difference between the left and right side of the photograph using an internet search engine. Key words: Shenandoah Mountains, haze

Discussion:

1. *What is the difference between the two pictures?*
   There is less visibility in the right hand side which is caused by haze. Shenandoah National Park in Virginia is one of the places in our state most affected by poor air quality that results in haze and reduces visibility.

2. *What is haze?*
   Haze is caused when sunlight encounters tiny pollution particles in the air. Some light is absorbed by the particles. Other light is scattered before it reaches an observer. More pollutants in the air mean more absorption and scattering of light, which reduce the clarity and color of what we see. Some types of particles, such as sulfates, scatter more light than others, particularly during humid conditions.

   The degree of impairment depends on a number of factors—the concentration, size, and chemical composition of these fine particles, relative humidity, and the angle at which the sunlight penetrates the haze. In rural parts of the eastern United States, fine particle sulfate accounts for most of the visibility impairment. Two-hundred times smaller in diameter than a human hair, these particles are just the right size to scatter visible light.
   http://www.nps.gov/shen/pphtml/23highlights500.html

3. How can haze be caused naturally?
   Natural sources can include windblown dust and soot from wildfires. Shenandoah National Park is part of the Blue Ridge mountains, a heavily forested mountain chain. In the process of photosynthesis, converting light, water, and minerals into carbohydrates, green plants give off water. From a distance this air-borne water creates a faint haze giving the Blue Ridge its name.

4. *How can haze be caused by humans?*
   Important sources of particulates are power plants, refineries, mining operations, and motorized vehicles.

5. *What do the words "Code Red" usually mean?*
   Code Red usually refers to a dangerous situation. The Environmental Protection Agency (EPA) has color designations for daily air quality. See http://www.epa.gov/airnow/aqibroch/aqi.html for more information.

6. Are the Shenandoah Mountains in a "Code Red" situation? Use the following websites to research what a code red means to a national park. What group has given the Shenandoah Mountains a "Code Red" for air quality?
   http://www.npca.org/across_the_nation/visitor_experience/clear_air/code_red/default.asp
   http://www.vcnva.org/news/news_articles/2004/06/27a.php

Extensions: Research power plants and mining operations around Shenandoah National Park. Where are most power plants found? Where are the largest mining operations found? How do the particles from these facilities get to Shenandoah National Park?

Activity 1B *Visualizing Air Pollution: Air Quality – Why does it matter*

Related Standards of Learning: Science: 6.4, 6.6, 6.9
Mathematics: 6.1, 6.8

Objectives: The student will:

- research health effects caused by breathing highly polluted air.
- interpret information found on the Virginia Department of Environmental Quality website to determine areas of the state with the highest ozone and particulate levels.
- differentiate between ground-level ozone and particle pollution and explain measurement units for each.
- graph and interpret for the local area the data of eight hour ozone exceedences for the years 1990-2004.

Materials Needed: Computers with internet access.

Procedure: ***Background.*** Think about the summer of 2005. What were the weather conditions? Were there any days when activities were cancelled or cut short because of the air? What kinds of warnings were issued from the media? What kinds of health concerns were there? What groups were the most vulnerable? What happens in the human body on days with unhealthy air quality?

This activity will answer these questions and examine the actions taken by the Virginia Department of Environmental Quality (DEQ) to minimize these health risks.

A: Exploring Asthma and the Air Quality Index (AQI)

1. Watch the "What's Asthma All About?" movie and answer the following question about the movie.
   - What are some triggers—different environmental stimuli that cause an asthma attack?
2. Review the Effects of Common Air Pollutants.
3. Obtain the real time ozone or particle pollution levels for your area through the Virginia DEQ or AIRNow website.
   - Do you think the current air quality levels might cause a person with asthma to suffer from an asthma attack? Why or why not?
   - Do you think the current air quality levels might affect a person with cardiovascular disease? Explain.
4. Look at the current air quality map of U.S.
   - Is there another area of the country that might pose a health threat to people who live there that have asthma? Where?
5. What can a person with asthma do to limit exposure to triggers?

B. Using Health Related Data. Using the American Lung Association data, click on your state and county and answer the following questions. If your county is not listed, select one that is closest to you.

1. What is your county's grade for High Ozone Days?
2. What is your county's grade for Particle Pollution?
3. What is your county's Total Population?
4. How many people are diagnosed with the following diseases in your county and what is the percentage compared to the total population for your county?

	Number of people	Percent
County name –		
Pediatric Asthma (Children under the age of 14)		
Adult Asthma		
Chronic Bronchitis		
Emphysema		
Cardiovascular Disease		

5. Click back to your state's data and click on the "Groups at Risk" tab. Which county in your state has the highest percentage of people diagnosed with the following diseases and how does it compare to your county?

	Number of people	Percent	Comparsion
County name –			
Pediatric Asthma (Children under the age of 14)			
Adult Asthma Chronic Bronchitis Emphysema Cardiovascular Disease			

C. Using the Air Quality Index (AQI)

Using the American Lung Association data, http://www.deq.virginia.gov/airquality/ and http://airnow.gov/ answer the following questions.

1. Why do you think the American Lung Association would collect information on air pollution and the number of people with asthma, bronchitis, emphysema or cardiovascular disease?
2. If you were diagnosed with one of these diseases, how could you use the real time air quality information to plan your daily activities?
3. What time of day is the AQI the highest? What time of day is the AQI the lowest? Would this help you answer #2 (above)?

Group Discussion

Use the following websites to answer the questions.

http://www.airdefenders.org/teacher/supportDocs/AsthmaBasics.pdf
http://www.deq.virginia.gov/airquality/
http://airnow.gov/

- Do you think air pollution is an issue we should be concerned with? Why or why not?
  Student answers.
- Do you think air pollution effects the environment?
  Student answers.
- What do you think will happen to air pollution levels as the world population keeps increasing? Why?
  Student answers.
- Is there anything that you can do to help decrease the amount of air pollution? Explain.
  Student answers.

Extensions Using the DEQ website, graph the exceedences data for ozone from 1990-2005 for your county. Choose a county in a highly urban area and a county in a rural area. Graph ozone data for these counties on the same graph.

- Which year had the worst ozone problems?
- Which year had the least ozone problems?
- Are there any trends? What kinds of predictions can you make from your graph?

Case Study: London

- Read about *London's Historic "Pea-Soupers"* and the American Lung Association's report on the *Lethal London Smog of 1952*
- How long has air pollution been a problem in London?
- What happened to change the way people thought about burning coal?

Activity 2 *Measuring the Acidity of Rain*

Related Standards of Learning Science: 6.6, 6.7, 6.9

Objectives The student will:

- Compare the pH of rain with that of distilled water, groundwater, tap water, and pond water.

Materials Needed

- Several clean containers, washed in hot soapy water, triple rinsed in distilled water.
- Water from several different sources, fresh rainwater, distilled water, tap water, groundwater from a lake, pond, swamp, stream or river
- Wide and narrow range pH paper

Procedure

1. Review pH, the pH scale, acids and bases.
2. This activity should be conducted during or immediately after a rain.
3. Collect fresh samples from as many different sources as possible.
4. Use the wide range pH paper to get an estimated pH of the water.
5. Use the narrow range pH paper to get a more accurate pH measurement.
6. Draw a pH scale (from 0 to 14). Indicate the pH of the different types of water tested on the scale.

Discussion

- Which type of water was the most neutral (closest to 7)?
  Distilled water should be neutral.
- Were any types of water basic/alkaline?
  Unless the water has been treated/softened or runs through an area high in limestone, most water will be slightly acidic.
- Was the fresh rainwater acidic?
  Student answers.
- What are some of the causes of rain that is highly acidic (pH = < 5)?
  Sulfur dioxide, nitrogen oxide emissions from power plants, refineries, mining operations, motor vehicles.
- How can particulate matter from emissions from power plants in other states cause acid rain in Virginia?
  Air currents can move particulate matter across state lines. The particulates form compounds with water vapor molecules. General, unbalanced equations:

  $S + H_20 \blacktriangleright H_2SO_3$ *or* H_2SO_4 *(sulfuric acid)*

  $N_2 + H_20 \blacktriangleright HNO_2$ *or* HNO_3 *(nitric acid)*

Extension Research plant species that are not pollution tolerant in the Shenandoah National Park area. Predict what will happen to these plants if the number of "code red" days increases.

Activity adapted from http://www.hcdoes.org/airquality/pdf/AQActivitiesbook.pdf

Activity 3 *Measurement of Particulate Matter: Dust Fall Slides*

Related Standards of Learning Science: 6.1, 6.6, 6.9
Mathematics: 6.5, 6.9, 6.10

Objectives The student will:

- Evaluate and rank the amount of particulate matter in and around the school campus.
- Predict and infer the places on a school campus that have high levels of particulate matter.

Materials Needed

- Microscope slides (10 slides for each group of four) (May use thick plastic cut into slide lengths.)
- Petroleum jelly (Vaseline)
- Coffee filters
- Balance sensitive to 0.01 g
- Marker
- Metric ruler

Procedure

1. Review definitions of air-borne particulates (particulate matter). Include inorganic and organic particulates (mold).
2. Divide students into groups of four.
3. Each group lists10 places in and around the school campus that will be undisturbed for 48 hours.
4. Predict and rank which places will have the most particulates (#1) to the least (#10)
5. Give each group 10 microscope slides, 10 coffee filters and a marker.
6. Put a small dab of petroleum jelly (Vaseline) on each slide. Spread a thin coat over entire slide. Place each thinly coated slide on a coffee filter.
7. Determine the mass of each slide. Write the mass on the coffee filter. Label this mass BEFORE. Keep the slide in the filter. Label each filter with a different location.
8. Take the slides to all 10 locations.
9. Leave undisturbed for 48 hours.
10. After 48 hours, collect the slides in the filters.
11. Determine the mass of each slide. Write the mass on the filter. Label this mass AFTER.
12. Subtract the mass of the slides. AFTER – BEFORE = particulate matter collected in 48 hours.
13. Record the masses.
14. Rank actual results from 1-10.
15. Record any other observations.

Location in and around school campus	Prediction ranking	Mass of slide/Vaseline BEFORE (g)	Mass of slide/Vaseline & particulate matter AFTER (g)	Actual ranking	Additional observations (Macroscopic or microscopic)

Discussion:

1. Could you accurately predict which location would have the most particulate matter?
   Student answers.
2. Why are there different amounts of particulate matter in different locations?
   The amount of particulate matter may depend on proximity to drafts or wind currents, ventilation systems, water vapor, or motor vehicles.
3. If you were to repeat this activity, what changes could you make to increase accuracy?
   Student answers.
4. With the metric ruler, measure the slide with the most particulate matter. Determine the amount of particulate matter in 1 cm_. Determine the amount of particulate matter in 24 hours. How much particulate matter would there be in one month (30 days)?

Examine the slides under a microscope. Is particulate matter homogeneous or heterogeneous? What kinds of particles may be on the slides?

Extension: Try the same experiment with potato slices. After 48 hours carefully place the slices into lunch baggies. Observe over two weeks. Safety note: Do not seal bags. Autoclave or use proper disposal for potentially hazardous waste.

Activity 4 *Observing Effects of Acid Rain*

Related Standards of Learning

Science: 6.6, 6.7, 6.9

Objectives

The student will:

- demonstrate the effect of acid rain on buildings and statues.

Materials Needed

- Paper Clip
- Chalk
- Clear Plastic Cup
- Vinegar

Procedure

1. *Note:* For visual impact, do this activity as an instructor demonstration. Use limestone instead of chalk. Use sulfuric and nitric acids with a pH of 4-6 instead of acetic acid (vinegar).
2. Review strength of acids. Acids with a pH of 5 are 10x more acidic than those with a pH of 6.
3. Use the paper clip to make a "statue" out of the chalk: write your name, draw a face, etc.
4. Place "statue" in the clear plastic cup.
5. Add vinegar, the "acid rain," to the cup.
6. Observe what happens to the "statue."

Discussion

- What change did you observe in the "statue"? Why do you think this change occurred?
  Student answers.
- What conclusions might you come to about the effect of acid rain on buildings?
  Rain that is highly acidic can cause structural damage, material degeneration, aesthetic degeneration, maintenance and repair costs.

Activity adapted from http://www.hcdoes.org/airquality/pdf/AQActivitiesbook.pdf

Activity 5 *Pollution Solutions*

Related Standards of Learning

Science: 6.2, 6.6, 6.9

Objectives

The student will:

- describe and characterize the major air pollutants.
- discuss alternatives to conserve energy and reduce these pollutants.

Procedure

1. Review fossil fuels, renewable and nonrenewable energy sources.
2. Divide students into groups of 3-4.
3. List the major air pollutants. Define each of these pollutants. Note that many of these pollutants also are connected to the use of non-renewable resources, especially fossil fuels.
4. Describe behaviors or changes that could be made to decrease or eliminate these pollutants.

Key:

Sources of Pollution	*Major Air Pollutants*	*Solutions: What we can do to decrease the pollution?*
Use of Motor Vehicles	Ozone	▪ Walk ▪ Bicycle ▪ Take public transportation ▪ Carpool ▪ Plan errands carefully to minimize car trips
	Carbon Monoxide	
	VOCs (Volatile Organic Compounds)	
	Nitrogen Dioxide	
Heat and Electricity	Particulate Matter (dust, smoke, soot)	▪ Turn off lights, computers, electronic devices when not in use ▪ Choose energy-efficient appliances; ▪ Limit wood fires
	Sulfur Dioxide	

Pollution Solutions

Sources of Pollution	*Major Air Pollutants*	*Solutions: What we can do to decrease the pollution?*
Use of Motor Vehicles		
Heat and Electricity		

Activity 6 *The Role of Property Rights*

Related Standards of Learning

Science: 6.6, 6.9

Objectives

The student will:

- understand that air is shared by everyone.
- understand that air has no boundaries.

Materials Needed

- masking tape
- 15 dried beans
- 15 dimes
- 15 quarters (or other small rewards of differing value)

Procedure

Background: A pond full of fish is located on public land, and anyone may come there to fish. Another pond nearby is also full of fish, on private land. The owner of the property sells fish from his pond. Soon, there are very few fish in the public pond but many fish in the private pond. How can you explain this?

1. Introduce and review the "Tragedy of the Commons" and the concept of pollution permits.
2. Tape 2 large squares on the floor in the center of the room. Divide one of the squares into a number of smaller sections. Select 8-10 students to participate in the first round. Make sure that the squares are in a position where students observing the activity will be able to see.
3. The taped area without sections is the "public pond," and any student may fish. Scatter the 15 beans (the "fish") on the public pond. Give the students standing around the square the following instructions:
   - When I say "Go," you may enter the square and pick up the beans.
   - I'll pay 10¢ for each bean picked up in the first round.
   - I'll pay 25¢ for each bean picked up in the second round.
4. Say "Go" and keep time for one minute. Make sure no one hides beans. They must turn in all harvested beans at the end of the minute. Because students will not be able to trust others not to harvest the limited "resource," you will not have to play the second one-minute round.
5. Ask students to return to their seats. Choose a new set of participants. You will be using the second square, so choose the same number of students as you have sections. After students line up around the edges, assign each student the "ownership" of a particular section. They each "own" a small pond, and can only fish in their particular section.
6. Repeat your instructions from procedure #2. Play the 2 rounds and pay students for the beans.

Discussion

1. Why did the first group fish right away, while the second group saved their fish for the second round?
   The first group had unlimited access to the pond.
2. Who owns the fish in the public pond? Would people fishing there worry about preserving the fish population for the future? Why or why not?
   No one, there is no incentive to conserve.
3. Who owns the fish in the private pond? Do you think the owner of the private pond is concerned with preserving the fish for future years? Why or why not?
   The private pond has an owner. Yes, the owner has the incentive of future profit.
4. Who owns the air we breathe? Who is responsible for preserving clean air for the future?
   No one has ownership. Everyone is responsible for preserving the air.
5. After completing this activity, do you think pollution permits would be effective? Why or why not?
   Student answers.

Adapted from http://fte.org/teachers/programs/efl/lessons/fri/eflfri2.htm

Activity 7 Build a Wet Scrubber for Cleaning Air Emission

Related Standards of Learning

Science: 6.9

Objectives

The student will:

- build a model of a wet scrubber.

Materials Needed

- paper towels
- 12-cm piece of glass tubing
- three 2.5-cm pieces of glass tubing
- three 55-ml flasks
- two glass impingers (glass tubing drawn at one end to give it a smaller diameter so as to let out smaller bubbles)
- heat source (burner or hot plate)
- three 2-hole rubber stoppers (of a size to fit the mouths of the flasks)
- two 30-cm pieces of rubber tubing
- ringstand apparatus
- vacuum source

Procedure

Background information: The wet scrubber is one of the most common pollution control devices used by industry. It operates on a very simple principle: a polluted gas stream is brought into contact with a liquid so that the pollutants can be absorbed.

1. Review pollution emissions from power plants, refineries, and mining operations.
2. Set up the apparatus as shown in figure 1. Put a paper towel in a 55-ml flask and place this above the burner.
3. Using a 2-hole stopper that makes an air-tight seal with the flask, insert a 12-cm section of glass tubing through one of the holes. The tubing should reach to approximately 1.2-cm from the bottom of the flask.
4. Insert a 2.5-cm piece of glass tubing into the other hole of the stopper.
5. Connect a 30-cm piece of rubber tubing to the 2.5-cm piece of glass tubing, making sure an air-tight seal exists.
6. Fill a second 500-ml flask approximately 3/4 full of water. Using a second double-hole stopper, put a 2.5-cm piece of glass tubing into one of the holes, and insert the glass impinger into the other.
7. Construct a third flask like the second.
8. Connect the rubber tubing and heat the first flask (combustion chamber) until smoke appears.
9. Put a vacuum on the third flask to draw a stream of smoke through the second flask (the wet scrubber). If smoke collects in the second flask above the water, a second scrubber can be added.
10. Ask the students if particles are the only pollutants produced by industry. Discuss how a wet scrubber collects not only particulate matter, but also captures waste gases. Demonstrate how the water scrubber works. Discuss that the white plume you see coming from a smokestack may really be steam coming from a water scrubber.
11. After observing the wet scrubber, answer the following questions:

Discussion

- Why does the water in the wet-scrubber change color?
  Particles being pulled in cause the color change.
- Why does the wet-scrubber have an impinger (in other words, why is it important for small bubbles to be formed)?
  Waste gases are being filtered also.

- What does the scrubber filter out of the air? Not filter out?
  The scrubber filters particulate matter trapped in the air. Particulates are then trapped in the steam (water).
- Suggest ways to dispose of the pollutants that are now trapped in the water.
  Condensers, collections tanks, wastewater treatment plants.
- What do you think might be some of the difficulties with cleaning larger amounts of pollution from the air?
  It is difficult to recapture all particulates. Another difficulty with scrubbers is treating the large volume of wastewater that is generated; some plants may need their own water treatment system.

Activity 8 *Fuel Costs and Consumer Decisions*

Related Standards of Learning
Science: 6.2, 6.9
Mathematics: 6.6

Objectives
The student will:
- compare the cost of driving an energy efficient vehicle with one that is less energy efficient.

Procedure
Background: Sport utility vehicles and light trucks, which have been very popular in the United States, use more gasoline and produce more air pollution than smaller, more efficient vehicles.

1. Review fossil fuels, non renewable resources, hydrocarbons.
2. In the chart below, calculate the difference in cost for SUVs versus hybrid cars, which require less gasoline.

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles					
Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car	$2.00	50		200	
SUV	$2.00	20		200	

Hint: Price of gasoline divided by miles per gallon is the cost of gasoline per mile. Cost per mile multiplied by miles per week gives total gas cost per week.

3. Now, suppose that the price of gasoline increases to $4.00.

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles					
Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car					
SUV					

ANSWER KEY

Table 1. $2.00/gal gasoline

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles					
Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car	$2.00	50	$0.04	200	$ 8.00
SUV	$2.00	20	$0.10	200	$20.00

Table 2. $4.00/gal gasoline

Weekly Gasoline Costs of Hybrid Cars and Sport Utility Vehicles					
Vehicle	Price of Gasoline ($/gal)	Miles per Gallon (mi/gal)	Cost per Mile ($/mi)	Total Miles per Week (mi/week)	Gas Cost per Week ($/week)
Hybrid Car	$2.00	50	$0.08	200	$16.00
SUV	$2.00	20	$0.20	200	$40.00

Discussion

- At $2.00/gal how much more per week does it cost to buy gasoline for a SUV than for a hybrid?
  $12.00
- At $4.00/gal how much more per week does it cost to buy gasoline cost for a SUV than for a hybrid?
  $24.00
- How much would the savings be over a year?
  $1,248
- Do you think drivers are likely to drive more, less, or the same number of miles?
  Student answers.
- What do you think will happen to the popularity of hybrid cars?
  Student answers.

Extension Research the cost of purchasing a hybrid car vs. the cost of purchasing an SUV. What are the advantages of owning a hybrid car? An SUV? What are the disadvantages of owning a hybrid car? An SUV?

Activity 9 *Allocating Scarce Resources*

Related Standards of Learning

Science: 6.9

Objectives

The student will:

- evaluate all methods of allocating a limited number of bicycle parking permits.
- choose the method that is most fair.
- justify the choice.

Procedure

Background: One of the basic functions of economics is rationing goods and deciding who gets how much of the goods produced. When the government decides that people do not have the right to produce as much pollution as they want to, the right to pollute has to be rationed.

In this activity, students will determine who gets a bicycle parking permit and who does not. Students will evaluate some of the costs and benefits of different ways of distributing bicycle permits.

1. Review policy options – bans and quotas, command and control, taxes and subsidies, and pollution permits.
2. Suppose there is only one bike rack at school, with room for only 10 bicycles. All bicycles must be parked on the rack. More than 10 students would like to bring bikes to school, so the principal decides to issue permits for bike parking.
3. Think of some ways the principal might decide who gets a bike permit. Here are some possibilities:
   - First come, first served: the first 10 students who come to the principal's office get the permits.
   - Lottery: The principal chooses names from a hat to decide who gets the permits.
   - Geography: The principal gives the permits to the students who live closest to the school.
   - Reward: The principal gives the students with the highest grades the bike permits.
   - Auction: The principal sells the permits to the highest bidder.

Discussion

- What are some of the benefits to each of these solutions? What are some of the costs?
  Student answers.
- In each case, is the person who wants the bike permit the most likely to get it?
  No, except in the case of the first come first serve scenario.
- Which person would give up the most for a bike permit? Why might other students not be willing to give up very much?
  The person with the least alternatives and most income.
- What do you think would be true of the highest bidder for a pollution permit?
  The person with the least alternatives and most income.

Extension

Research the Clean Air Act. When was it first promulgated? What was the reason for the Clean Air Act? How has the Clean Air Act affected Virginia? Research current air policies in Virginia. How does Virginia enforce the policies?

Air Pollution At a Glance

Major Man-Made Air Pollutants

A chart summarizing major air pollutants that can be used as a reference for several activities.

Pollutant	***Description***	***Sources***	***Signs/Effects***
Carbon Monoxide (CO)	Colorless, odorless gas	▪ Vehicles burning gasoline ▪ Indoor Sources, including kerosene, natural gas, coal or wood-burning stoves and heaters	▪ Headaches, reduced mental alertness, death ▪ Heart damage
Lead (Pb)	Metallic element	▪ Vehicles burning leaded gasoline ▪ Metal refineries	▪ Brain & kidney damage ▪ Contaminated crops & livestock
Nitrogen oxides (NOx)	Gaseous compounds made up of nitrogen & oxygen	▪ Vehicles ▪ Power plants burning fossil fuels ▪ Coal-burning stoves	▪ Lung damage ▪ React in atmosphere to form acid rain ▪ Deteriorate buildings & statues ▪ Damage forests ▪ Form ozone & other pollutants (smog)
Ozone (O_3) (Ground level)	Gaseous pollutant	▪ Vehicle exhaust & certain other fumes	▪ Lung damage ▪ Eye irritation ▪ Damage crops ▪ Reduced visibility ▪ Discolors buildings & statues
Particulate matter	Very small particles of soot, dust or other matter, including tiny droplets of liquids	▪ Diesel engines ▪ Power plants ▪ Industries ▪ Windblown dust ▪ Wood stoves	▪ Lung damage ▪ Eye irritation ▪ Crop damage ▪ Reduces visibility ▪ Discolors buildings & statues
Sulfur dioxide (SO_2)	Gaseous compound made up of sulfur & oxygen	▪ Coal-burning power plants & industries ▪ Coal-burning stoves ▪ Refineries	▪ Eye irritation ▪ Lung damage ▪ Kills aquatic life ▪ Reacts in atmosphere to form acid rain ▪ Damages forests ▪ Deteriorates buildings & statues

In the Driver's Seat

Activities from Project Learning Tree focusing on fuel economy, alternative means of transportation and what can be done to improve it.

Levels Grades 5-8

Subjects Science, Social Studies, Math,

Concepts

- By reducing waste and recycling materials, individuals and societies can extend the value and utility of resources and also promote environmental quality. (5.4)
- Consumers "drive" the marketplace with their demands for goods and services. Such demands shift with time and may have positive or negative effects on the resource base and environmental quality. (15.2)
- Increased public knowledge of the environment and the need for conservation of natural resources have resulted in lifestyle changes in many cultures. (15.5)

Skills Identifying Relationships and patterns, Analyzing, Making Decisions, Organizing Information

Objectives Students will:

- gain knowledge about the differences in fuel economy between different vehicles and
- explain strategies for reducing the amount of fuel used by vehicles.

Materials Consumer magazine with information about 20 or more different vehicle makes and models; chart paper; pens or crayons; chalk or rope; copies of student page ***

Time Considerations Preparation: 20 minutes
Activity: Two 50-minute period

Overview In this activity, students learn about gasoline, then explore fuel conservation and energy efficiency by simulating the distance they can travel on a set amount of gasoline using different vehicles.

Background Transportation plays an important part in our everyday lives. We rely on cars, buses, trains, bicycles, and even our own feet to take us where we need to go. All of these methods are powered by some source of energy. For example, most cars today run on gasoline.

Gasoline is a refined product of crude oil, or petroleum. The word petroleum comes from the Latin words "petra" meaning rock and "oleum" meaning oil. Petroleum is a fossil fuel formed millions of years ago from the remains of microscopic organisms. As these tiny plants and animals died they sank to the sea floor, and over many centuries they were buried with sand and mud. With increased pressure and heat from the layers above, the tiny organisms were transformed, ever so slowly, into hydrocarbons, the building blocks for petroleum and natural gas.

Most of the petroleum consumed in the United States is used for transportation. The process to convert petroleum into gasoline and other products begins at the refinery. The United States has more than 170 active refineries.

Follow the refinery process on the teacher page. From a well to a pipeline, the incoming petroleum is treated to remove sulfur, nitrogen, and trace metals. The next step takes advantage of the fact that different hydrocarbons boil at different temperatures. In a fractionating tower the petroleum is heated until it boils. Horizontal trays divide the column at different levels. As the petroleum boils, it vaporizes. Each hydrocarbon rises to a tray at a temperature just below its own boiling point. There, it cools and turns back into a liquid. This process separates the petroleum into different products. These products go through additional processing (cracking/coking, alkylation, blending and removal of impurities) to become the products we use each day.

Improved refining technologies have made it possible to produce more than 19 gallons of gasoline from a barrel (42 gallons) of petroleum. This is a remarkable advance over the industry's early days, when a barrel of petroleum yielded just 11 gallons of gasoline. Diagram 1 shows the percentage of different products that are refined from a typical barrel of crude oil.

The final step of the refining of gasoline is purifying and fine-tuning the fuels to meet today's performance and environmental standards. Additives that keep engines clean and increase oxygen help today's gasolines burn cleaner.

While gasoline is a versatile fuel, yields a relatively high amount of energy, and is easy to transport, when combusted (burned) it releases carbon dioxide and other pollutants into our atmosphere. Over the years, technological advancements have led to many improvements in automobile emissions and fuel economy. Those improvements have included the introduction of catalytic converters, the construction of lighter and more energy efficient cars, and the development of cleaner fuels (by eliminating lead in gasoline and reducing the amount of sulfur in diesel fuel).

Much can be done on the part of consumers to ensure this progress continues. One example is to use gasoline more efficiently by carpooling, planning trips more efficiently, and getting regular tune-ups for your car. Another example is to find alternatives to driving such as walking, bicycling, and using public transportation.

One of the most important environmental decisions a consumer can make is choosing a car with good fuel mileage. In general, small cars have better fuel economy than larger cars, and cars have better fuel economy than vans, sport utility vehicles, and trucks. Fuel economy is measured in terms of miles per gallon, that is, the number of miles you can drive in that vehicle on a gallon of gas.

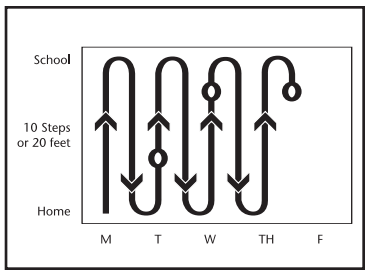
Electric vehicles are gaining attention as an option for reducing air emissions. However, their use is limited because the batteries are expensive, heavy, and store little power, allowing a car to travel only 60-70 miles on a charge.

Electric vehicles are sometimes referred to as "zero-emission" vehicles because they produce virtually no pollution through fuel evaporation or burning. However, while electric cars themselves are clean, generating the electricity to charge the vehicle batteries produces air pollution and solid waste.

Hybrid vehicles, which combine two power sources, are another option to reduce gasoline use. These vehicles have a small, clean, internal combustion engine combined with an electric motor powered by batteries. They recover energy when braking, will shut off the gasoline engine when stopped, use advanced aerodynamics to reduce drag, use low-rolling resistance tires, and use lightweight materials to reduce the weight of the vehicle. This combination of features allows these hybrid cars to achieve better gas mileage and still have a similar range, performance, and convenience of conventional gasoline cars.

Fuel cells are yet another viable alternative fuel source for vehicles. Like batteries, fuel cells rely on chemical reactions rather than combustion. Many fuel cell prototypes have been developed but cost continues to be a challenge.

Getting Ready Review the sample travel log on page 29. View the EPA website http://www.fueleconomy.gov. Become familiar with the process of looking up different vehicles and determining the miles per gallon the vehicles achieve. On a playing field or in a multi-purpose room, mark two lines that are about 10 steps apart (20 feet). Label one line "home" and the other "school." Divide the width of the area into 5 days—Monday through Friday. See Diagram at right.



Doing the Activity

Part A

1. Begin a discussion with your students about how they get around in their community. What methods of travel do they use? What sources of energy do they use? How far do they travel? Keep a list of their answers to compare after they complete the Weekly Log.

2. Instruct students to calculate the amount of miles their family vehicle travels during a week. Students without vehicles should estimate the number of miles they travel (walk, bus, etc.). See the "Sample Travel Log" on the Teacher Page. Students should work with a parent or gaurdian and record the mileage of the vehicle(s) on Sunday evening. Throughout the week, they will log the use of the vehicle, the purpose of the trip, the type of travel, and mileage. They will record the mileage again the following Sunday evening.

3. Discuss the findings with the students. What was the average mileage per vehicle? Average mileage per student? Compare the findings with the list developed at the beginning of the activity.

4. Ask students what they think gasoline is made from? How is it made? Where do we get petroleum from? What are some different products that are made from petroleum? What different types of gasoline are they familiar with? Discuss how a refinery operates. Make a list of how students use gasoline. What are some impacts of using gasoline?

Part B

1. Ask students what type of vehicle they would like to drive. Why did they choose this vehicle?

2. Have students select and research a vehicle make and model of their choice. They should get a picture (newspaper, brochures, magazines) or create a drawing of their vehicle. The students should determine the number of people the vehicle holds and check the EPA Fuel Economy website for the mpg rating. Other information could include: type and size of engine, cost, and options that are available.

   Students will do a simulation in which they will use their vehicles to "drive" to school and then home again for 5 days. Give the students 3 poker chips to represent 3 gallons of gasoline. For the purpose of the simulation their vehicle will go "steps per gallon" instead of miles per gallon. For example, if the vehicle is rated 24 mpg, every 24 steps they will drop a chip to indicate they have used a gallon of gasoline.

   Have the students begin at the line marked home in the Monday area (See diagram). They will count the number of steps they take to travel to school (10) and then return home for Monday. They will drop a chip each time they use one gallon of gasoline. Do the same with Tuesday. Continue for one week. Have the students stop in place when they "run out" of gasoline. Which vehicles ran out first? Do any still have gasoline?

3. For Round 2, give each student 3 chips again. Challenge the students to think of a way to get the greatest amount of trips using the same amount of gasoline. How can they increase it? (They might suggest car-pooling but the limit is the number of people the vehicle holds).

4. For Round 3, give each student 3 chips again. A bus arrives that can carry 45 people and gets 5 mpg (EPA Estimate). Pooling the gasoline, how far can the bus go?

Enrichment

1. Students conduct a survey to determine the average vehicle occupancy in your community. First, choose an observation point that is safe and yet allows students a vantage point for seeing the number of people in vehicles passing by. Have students tally the number of passing vehicles and the number of people in each vehicle. Tallying works best with partners, with one person being the counter and the other being the recorder. Have students keep count for 10 minutes or until they record 100 vehicles. Compare the results for different times and, if possible, different sites in the community. Discuss how occupancy affects the amount of gasoline being used. What ways could your community try to increase the average vehicle occupancy?
2. Using Mapquest (www.mapquest.com) have students take a trip with a car. How many miles will they go? How many mpg will the car get? How many gallons will they need for the round trip? How much will it cost in fuel?

Assessment Opportunity

To assess students' learning, have them develop a poster, door hanger, or other public information piece that could be used to educate the school community about fuel economy and alternative modes of transportation. Their piece should include an explanation for why fuel economy and saving gas are important.

Related Activites

Waste Watchers, Energy Sleuths, On the Move

References

ABC's of Oil, Chevron Corp., http://www.chevroncars.com/know/oil/index/html.

Fuel Economy, United States Department of Energy and the United States Environmental Protection Agency, http://www.fueleconomy.gov.

MacKenzie, James J., Roger C. Dower, and Don Chen. The Going Rate: What it really costs to drive. World Resources Institute, 1992.

Wouk, Victor. "Hybrid Electric Vehicles," Scientific American. October 1997, p70-74.

Sample Travel Log

Vehicle _____ Model _____
Year _____ EPA Miles Per Gallon _____

Weekly Travel

First Sunday Mileage: _____ Total Miles Traveled: _____
Second Sunday Mileage: _____

Daily Travel

Day	Reason for Travel	Mode	Miles Traveled
Monday	Mom - to work	Car	15
	School	Walked	1
	Grocery Store	Car	6
	Visit a friend	Bike	1
	Mom - to library	Car	9
	Soccer - Mom and me	Car	10
	Daily Totals	Car	40
		Walked	1
		Bike	1
Tuesday	Mom - to work	Bus	15
	School	Bike	1
	Shopping - Mom and me	Car	17
	Music lesson	Car	7
	Daily Totals	Car	24
		Bike	1
		Bus	15

How Hybrid Cars Work – http://www.howstuffworks.com/hybrid-car.htm

HybridCars – http://www.hybridcars.com

Billy Brennan, "On the Move" Energy & Me, CD. Takoma Park, Maryland: Do Dreams Music; Washington, DC: Project Learning Tree.

American Petroleum Institute – http://www.api.org

U.S. Department of Energy – http://www.energy.gov

Mapquest – http://www.mapquest.com

Air We Breathe

Activities from Project Learning Tree focusing on indoor air quality and what can be done to improve it.

Levels Grades 6-8

Subjects Science, Language Arts

Concepts

- Pollutants are harmful by-products of human and natural systems which can enter ecosystems in various ways.(7.3)
- The structure and scale of an ecosystem are influenced by factors such as soil type, climate, availability of water, and human activities. (10.2)
- When the Earth is studied as an interacting ecological system, every action, regardless of its scale, affects the biosphere in some way. (10.3)

Skills Defining Problems, Observing, Comparing and Contrasting, Determining Causes and Effects, Identifying Attributes and Components, Analyzing, Interpreting, Solving Problems

Objectives Students will:

- identify various types of indoor air pollutants and their sources,
- understand how various pollutants can be harmful to people's health,
- trace how radon can get into buildings and eventually into our bodies,
- learn the connection between how radon is produced naturally and the role of radioactive decay in power production, and
- take action to improve indoor air quality.

Materials Part A: microscope slides or blank overhead transparencies, petroleum jelly, white paper, masking tape, magnifying glasses, wax paper, a boiled potato, microscope (optional)

Part B: copies of student pages 35, 36, and 37, balloon, felt-tip marker, handful of soil, large glass jar, water, blue food coloring, transparencies and overhead projector (optional)

Part C: copies of student page 38

Enrichment: copies of student page 39

Time Considerations Preparation: 40 minutes
Activity: Four 50-minute periods over a month (Part A); One or two 50-minute periods (Part B); One or two 50-minute periods, possibly over several weeks (Part C); Enrichment: 30 minutes plus homework

Overview Did you know that the air in our homes, schools and offices can sometimes be less healthy than the air outside? And that one of the most serious indoor air pollutants, radon, is actually produced naturally from the radioactive decay of uranium—the same process we rely on for our production of energy in nuclear reactors. In this activity, students will learn more about indoor air quality and what can be done about it.

Background This activity deals with indoor air quality. For a long time, when people talked of air quality, they meant the quality of the air outside and pollutants like acid rain, automobile exhaust, smokestack emissions, and smog. More recently, issues of indoor air quality have begun to attract attention as various human ailments have reportedly been linked to the quality of indoor air, and terms like "sick buildings" or "secondhand

smoke" are often used. Health experts are calling for routine testing of indoor air and for further study of indoor air hazards.

On the average, people in North America spend about 80 percent or more of their time indoors—working, cooking, eating, sleeping, watching television, shopping, and so on. The trend toward tightly sealed buildings and homes for energy conservation complicates problems of indoor air quality by preventing fresh outside air from replacing indoor air.

Indoor air pollutants come from a variety of sources that can lead to health problems. Small leaks from gas appliances can build up to dangerous levels. Potentially dangerous vapors are emitted from certain types of building materials such as carpets, drapes, ceiling panels, and plywood. Paints, pesticides, aerosols, air conditioners, household cleaners, and dust put pollutants in indoor air. Stoves, heaters, and fireplaces give off smoke, soot, and gases that can be harmful to human health. Tobacco smoke, including second-hand smoke, is one of the most dangerous indoor air pollutants.

Unfortunately, most pollutants are made of particles that are too small to see, and smell is not a reliable indicator. Many pollutants actually have a pleasing smell such as ingredients found in some perfumes and air fresheners, pipe smoke, and new leather that has been chemically treated.

Some indoor air pollutants are actually microscopic organisms such as mold, mildew, bacteria, viruses, and dust mites that can cause sickness or allergic reactions.

Of all indoor air pollutants, radon can be one of the most insidious. Radon is an odorless, colorless gas that occurs naturally in varying concentrations in all types of rock and soil. It is produced naturally from the radioactive decay of uranium. (In nuclear power plants, we take advantage of the natural radioactive decay of uranium, greatly accelerating the process in order to produce large amounts of energy, which are then available for our use. For additional information see page 128.) Radon breaks down into several radioactive particles that become attached to larger particles in the air. When inhaled, these particles get lodged in lungs and can increase the risk of lung cancer.

Radon differs from other indoor air pollutants in that it occurs naturally and enters buildings on its own. Radon gas constantly emerges from the earth and goes into the atmosphere. But when it seeps into the basement of a poorly ventilated home or building, it can accumulate in unhealthy amounts. Most radon that enters buildings comes through holes or cracks in the building's foundation. Radon also gets into buildings through well water and through building materials made from rock, brick, or concrete.

Getting Ready

Make copies of student pages 35-39.

Doing the Activity

Part A – Particle Pursuit

1. Ask students if they've ever seen indoor air pollution. Chances are they haven't seen much, because, for the most part, it's invisible.
2. Tell them they will learn about many types of indoor air pollution. Most of these pollutants are made of particles that are too small to be seen with the naked eye; however, some pollutant particles are large enough to see.
3. Divide your group into teams.
   Each team should have a flashlight, notebook, and pencil. (If you only have one flashlight, perform the activity as a demonstration.) Tell students that they will do this activity in the dark, so they should be careful and stay calm.
4. Close the blinds and turn off the lights. Show the students how particles in the air show up in the flashlight beam.
5. With the lights back on, tell each team to go to a different location in the room. Turn lights back off and

have them use the flashlight to see what's in the air. As one person holds the flashlight steady, the others should look at the projected beam and try to describe the particles they see and the relative abundance of different types of particles. Have students hold the flashlight very high and very low to see if there's a difference in the particles they see.

6. After about 5-10 minutes, turn the lights back on and have each team describe what they saw in their beams. Do not have them draw any conclusions at this point.
7. Tell students that they will now look for smaller particles. Give each team a microscope slide. (If slides are not available, cut an overhead transparency into strips approximately the size of microscope slides.)
8. Tell each team to smear a thin layer of petroleum jelly on the slide and to place it in a different location in the room or building. Make sure teams select a wide variety of locations such as on shelves or in closets. Two teams should put their slides outdoors (either on the window sill or taped to the window) for comparison with the indoor samples. Leave the slides in place for 24 hours.
9. The next day, each team should put their slide on a white piece of paper and study the particles that stuck to it. Students should use a magnifying glass and, if possible, a microscope to examine their slides. They should take notes of what they see, draw sketches if they want, and try to categorize the particles they find. Do their findings differ from what they saw in the light beam?
10. Each team should report its findings but students should not draw any conclusions at this time.
11. Finally, give each team a thin slice of boiled potato on a piece of wax paper. Take one slice, wrap it completely in wax paper, and put it in the refrigerator—this is the control slice. Tell students to put their slice in the same place they put their slides. The potato slice will collect particles the same way the slide did. The difference is that when biological pollutants such as bacteria, mold, and mildew land on the potato, they will grow into visible colonies.
12. Leave the potato slices in place for a week or two. Students should examine the slices every day with a magnifying glass, then make notes on different shapes, colors, and smells that they notice.
13. After this period, have each team report on what they saw on their slice. Besides other particles, do they notice growths, or any living colonies? Do they have an idea what these organisms are?
14. Have each team review its findings in each phase of the experiment: flashlight, slide, and potato. Students should draw conclusions as to what particles are present in the indoor air (soot, fibers, bacteria, mold, chalk dust).
    - Are certain people more sensitive than others to these pollutants? (Yes, people with allergies; for example, asthma. About 1 in 13 school-aged students has asthma and the cases of asthma have increased notably in the last 15 years.)
    - Do students think these pollutants are in dangerously high concentrations? (They will probably have to ask an air quality expert.)
    - How could the concentration of the pollutants be lowered? (Better ventilation or air-filtering devices could be installed.)

Part B – Invisible Gas Attack

1. Ask students if they've heard of radon, and if so, what are their perceptions? Using the background information, discuss a few facts about radon and its potential harm. Students should read "Invisible Gas Attack" on page 35.
2. Ask students what we mean when we say radon is a gas. Discuss how the characteristics of gases influence radon and its movement. Explain that gases will expand or move to fill up a space. Demonstrate movement by blowing up a balloon. As the gas (air) expands, the balloon gets larger.
3. Explain that gases such as air and radon move through soil slowly. When minerals decay or organic matter decomposes, the gases generated in these processes are released through the soil into the atmosphere. With the following experiment, demonstrate how air moves through soil:

- Put a large, clear glass jar of water in a place where it is easily visible and will not be disturbed. The water represents the soil. Put a large drop of blue food coloring, which represents air, into the water. Have students check the jar several times during the class to see how much the "air" has spread. Does it spread quickly or slowly? In any particular direction?

4. Radon can seep through all kinds of rock fractures. Fractures are cracks in bedrock that occur as a result of the natural forces inside the earth. Some rock types (such as limestone or shale) tend to have more internal fractures and cracks than other types. Cracks in the bedrock can also occur when different rock types are side by side.
5. Distribute "Where will the Radon Go" on page 36. Allow students 5 to 10 minutes to trace radon's route from the ground into the atmosphere or into people's homes.
6. Make a transparency of student page 270 and put it on an overhead projector. Ask several students to come forward one at a time to trace different radon routes, until all possible routes have been traced.
7. Distribute copies of "Trace the Radon Routes" on page 37 and repeat the same exercise as in Step 5 to see how radon might travel within a building. Discuss these questions with students:
   - How many different ways can radon enter a home?
   - What do you think happens to radon once it is in your home?
   - Can you get rid of radon once it is in your home? How?
   - How do you find out if your home is contaminated with radon?
   - What can you do to prevent radon from continuing to enter your home?

Part C – Air Patrol

1. Have the students read about "Primary Pollutants" on student page 38. Discuss with students the harmful effect each pollutant can have if it enters our indoor air supply in significant proportions.
2. Using this information, have students design a checklist to look for indoor air quality hazards in their own homes. (old garbage, excessive dust, chemical smells, mildew odors, tobacco smoke, gas leaks, crack in the foundation—possible radon)
3. Have students take their checklist home to inspect for potential air quality hazards. They should put a checkmark next to the ones they find and a star next to the ones they feel might be severe enough to warrant action.
4. After a few days, review the checklists with your students. Spend time discussing the starred items. Does the whole class think that these problems are severe enough to warrant action? Are there items on the list that weren't starred but should have been?
5. Have students suggest ideas on how they might remedy some of the problems they identified in their home survey of indoor air (test for radon; restrict indoor smoking; improve ventilation; clean or change filters in air conditioners, heaters, humidifiers, and purifiers; cultivate house plants; seal cracks in foundations; hang dry-cleaned clothes outside for a few minutes before bringing them in).
6. Have students choose a few actions they can take to improve the air quality in their homes, and give them several days or weeks to implement these improvements. At a set date, have each student give a progress report to discuss any changes or difficulties in making improvements.

Enrichment Give students the "Home Radon Exposure Survey" on student page 39 to fill out at home. You can suggest that students ask a parent to help them answer the survey questions. Have students report their findings.

Assessment Opportunity Have students list ways radon could potentially contaminate their homes. The students can make a cut-away drawing similar to the handout on page 37, to help them identify possible radon routes in their own homes.

Related Activites Air Plants, Pollution Search, Waste Watchers, In the Driver's Seat, Plant a Tree

References

A Citizen's Guide to Radon (2nd Edition) The Guide to Protecting Yourself and Your Family From Radon. Washington, DC: Environmental Protection Agency, A joint effort of EPA, U.S. Dept. of Health & Human Services and U.S. Public Health Service. September, 1994. Can download document from: http://www.epa.gov/iaq/radon/pubs/citguide.html

Radon in Schools (2nd Edition) Washington, DC: Environmental Protection Agency. A joint effort of National Educational Association, Parent Teachers Association & The American Lung Association. Oct., 1994. Can download document from: http://www.epa.gov/iaq/radon/pubs/schoolrn.html

Field, R.W., et. al. *Residential radon gas exposure and lung cancer: the Iowa Radon Lung Cancer Study.* American Journal of Epidemiology. 2000 151:1091-1102.

Swiss, Martha B. *Pollution Prevention of Our Land, Water and Air.* Pennsylvania: Air and Waste Management Association, 1993.

Air and Waste Management Association, One Gateway Center, Third Floor, Pittsburgh, PA 15222; 412-232-3444; http://www.awma.org

Student Page A *Invisible Gas Attack*

What Are Sources of Radon?

Radon is released as a gas when small amounts of uranium break down in the ground. Usually, the gas rises through the soil and escapes into the air outside where radon has low concentration and little effect on people inside buildings. However, when the rising gas releases into a house or other building, the radon seeps in and builds up to dangerously high levels.

Radon enters buildings through cracks and holes in the foundation such as cracks in a concrete floor or wall, drains in the floor, or holes around pipes that go through the floor or wall. Sometimes even well water can carry radon and release the gas into a house. Several things help radon to enter a building. Fans in kitchen ranges, bathrooms, and clothes dryers force air out of the house, creating a small suction that can draw radon into the house from the ground. Also, as warm air rises in a building, a draft forms, which can draw radon up through foundation cracks or holes.

How Does Radon Affect Health?

Radon gas forms tiny radioactive particles. Breathing carries the particles deep into the lungs. These particles then release small bursts of energy that can damage the lung tissue. This damage can lead to lung cancer later in life.

Breathing air with high radon levels is like smoking cigarettes. The more smoke or radon you breathe in, the higher your risk of getting lung cancer.

People who smoke and are exposed to radon have higher health risks than do nonsmokers exposed to radon, says the Environmental Protection Agency (EPA).

While scientists do not agree on exactly how great the health risk from radon is, there is little debate that the risk is serious. The longer the time and the higher the radon level a person is exposed to, the greater the risk of developing lung cancer. According to the EPA, testing your home is the only way to know if your health is threatened by radon.

How Widespread Is the Radon Risk?

The EPA estimates that millions of homes have high radon levels. Studies have also shown that radon is a problem in many school classrooms.

Since radon is found almost everywhere in our country, the EPA urges all homeowners and schools to test for radon. Although a house may have a low radon reading, each neighboring house should still be tested, because levels may vary widely from house to house even in the same neighborhood.

How Can You Deal with Radon?

Radon is a serious problem in many homes, but high levels of radon can be easily lowered. Experts are available who specialize in reducing high radon levels. The cost is usually comparable to the cost of many other home repairs.

The important first step is to test your home for radon to find out if there is a problem. For more information about how to test, call 1-800-SOS-RADON.

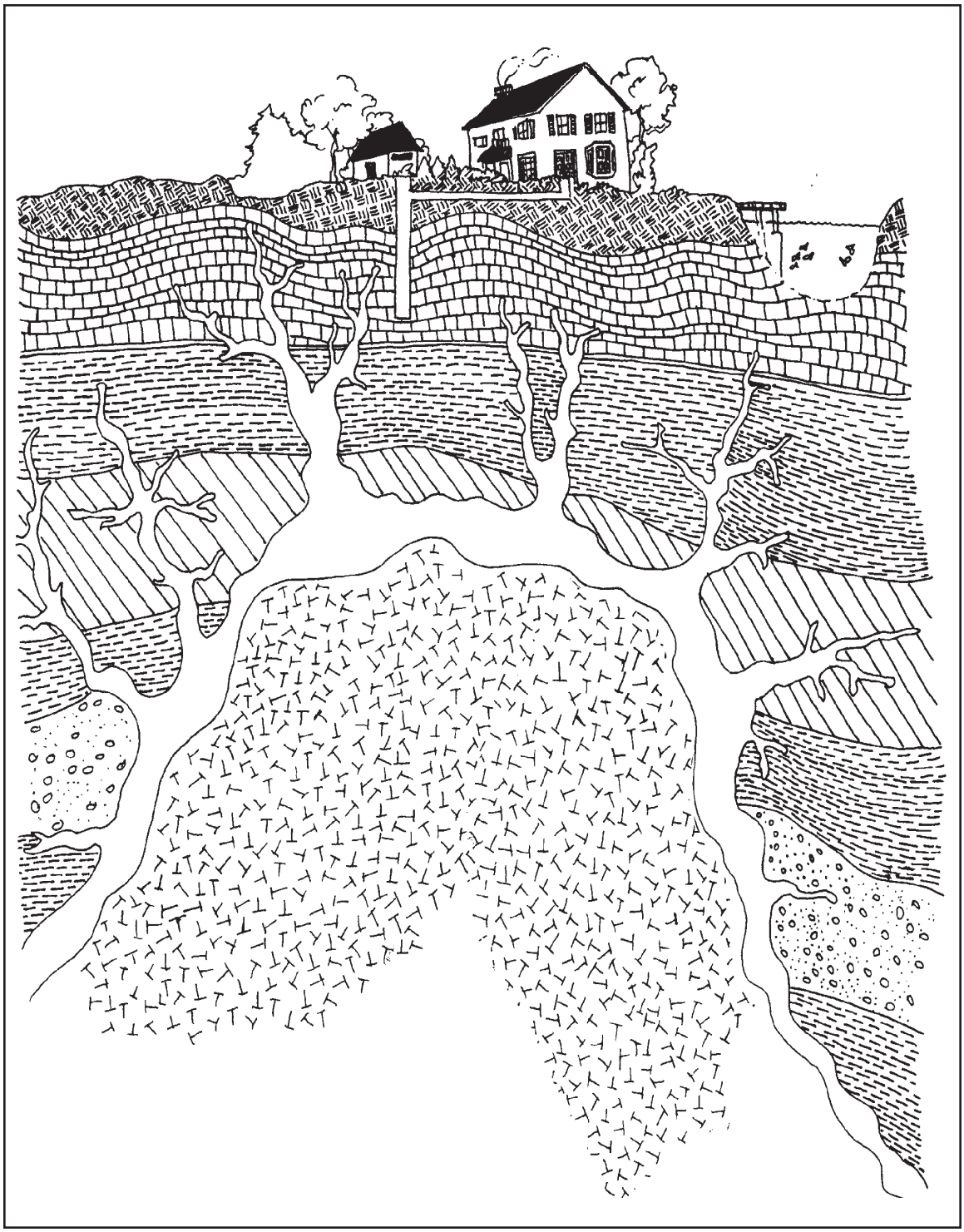
How Is Radon Detected?

Since you cannot see or smell radon, you need special equipment to detect it.

- Radon can be detected using small devices that measure radon in the air. These devices are called "radon detectors" and are sold in hardware or retail stores and by mail.
- The detector is left in a room for several days and is then sent to a laboratory to be analyzed. If the laboratory tests show a level of radon above 4 pCi/L, remedial action is called for. If levels are between 2 and 4pCi/L, then consider making changes whenever affordable.
- The two most popular, commercially available radon detectors are the charcoal canister and the alpha track detector. Both devices are exposed to the air in your home for a specified period of time and sent to a laboratory for analysis. Charcoal canisters have a test period of three to seven days and one canister costs approximately $10 to $25; alpha track detectors have a minimum test period of two to four weeks and one detector costs approximately $20 to $50.
- Other techniques used to measure radon levels may require operation by trained personnel, and such techniques may be more expensive than the devices shown above.

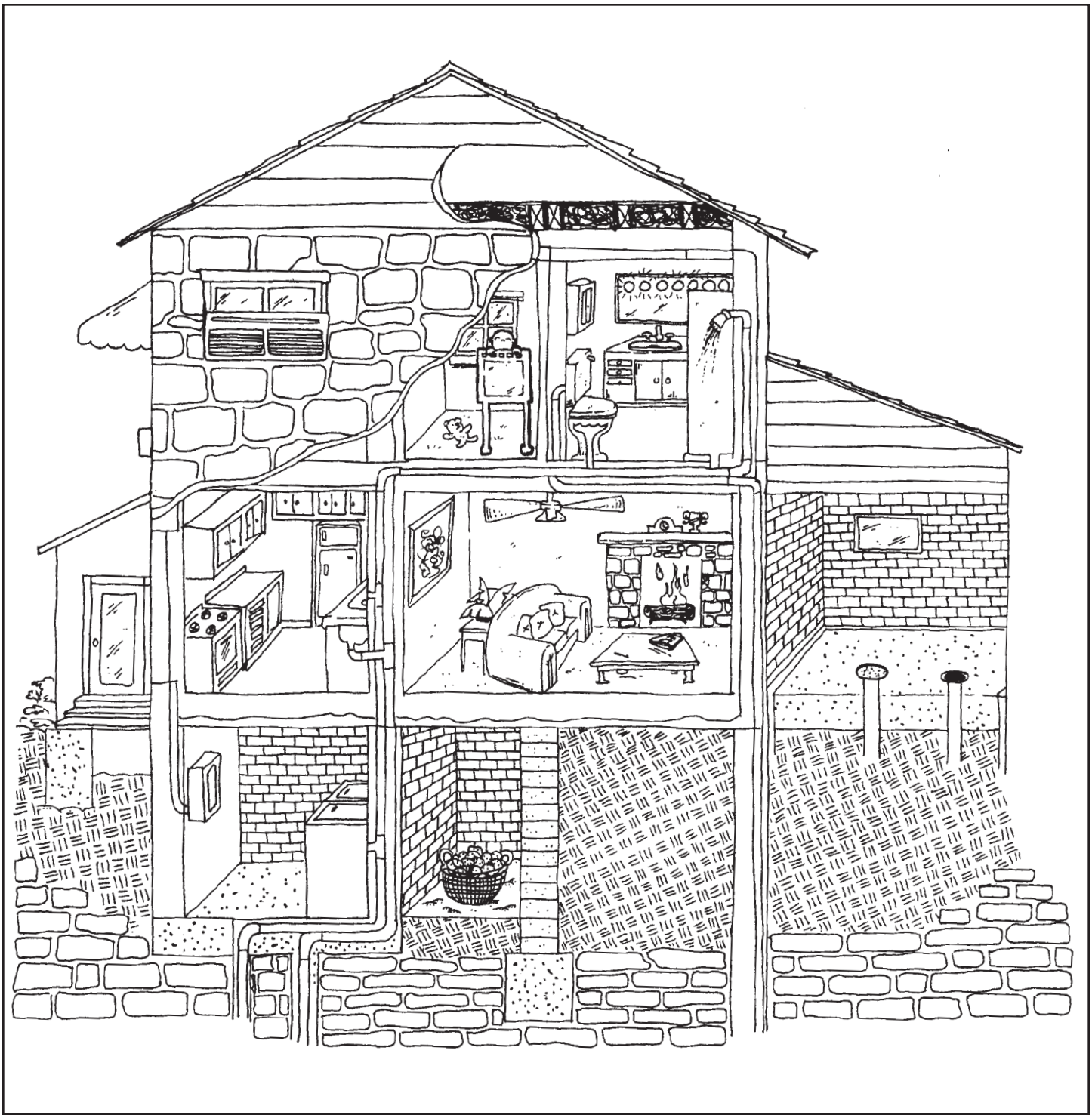
Student Page B *Where Will the Radon Go?*

Directions – Use a colored marker to trace radon's route from the ground into the atmosphere or into people's homes.



Student Page C *Trace the Radon Routes*

Directions – Use a colored marker to trace all the possible routes by which the radon may enter this home.



Student Page D *Primary Pollutants*

These indoor air pollutants pose health risks:

1. Radon
2. Formaldehyde (for-MAHL-duh-hide) and other Volatile Organic Compounds (VOCs)
3. Tobacco Smoke
4. Asbestos
5. Combustion By-products
6. Biological Pollutants

Radon Refer to Student Page A – "Invisible Gas Attack".

Formaldehyde and Other VOCs Volatile organic compounds are made of atoms that are found in various products such as glues, paints, and solvents. Although these compounds are "naturally" derived, they may pose serious environmental and health threats when in high enough concentrations or in poorly ventilated enclosures. Formalde-hyde, for example, is a common VOC found in furniture, foam insulation, plywood, carpets, drapes, particleboard, glues, and other building supplies. It irritates the eyes and nose, may cause respiratory ailments, and has been linked to cancer in laboratory studies. Other sources of VOCs are household cleaners and paints, wood finishes, pesticides, air fresheners; chemicals in carpeting and fabric; and dry-cleaned clothes. (Perchlorethyene, a VOC, is among the solvents used in the dry-cleaning process.)

Tobacco Smoke Smoke from cigarettes, pipes, and cigars contains many pollutants including inorganic gases, heavy metals, particulates, VOCs, and aromatic hydrocarbons. Unfortunately, people who don't smoke are still faced with the bad effects of breathing these VOCs. The latest EPA report says that secondhand tobacco smoke may cause 6,000 deaths and cases of cancer and heart disease each year in otherwise healthy nonsmokers.

Asbestos Asbestos was once a commonly used building and insulation material (until the 1970s in the United States). It was often mixed with a cement-like substance and could be conveniently sprayed or plastered on ceilings or other surfaces. With time, asbestos starts to disintegrate and it releases tiny fibers that float in the air. They can be inhaled and can lodge deep in lung tissue, which may cause lung cancer and asbestosis, a chronic scarring of the lungs that hinders breathing.

Combustion By–products The fuels we use in our homes for heat, hot water, and cooking can release pollutants into our homes. Kerosene, natural gas, and oil can give off nitrogen and sulfur dioxides, carbon monoxide, and formalde-hyde. Even wood burned in fireplaces gives off very fine particulates, which can be unhealthy to breathe.

Biological Pollutants Fungi and bacteria will grow in humidifiers and heating, ventilating, and air conditioning systems if they are not properly cleaned and maintained. These systems can also bring biological contaminants indoors and circulate them throughout a building. The contaminants can cause people to have allergic reactions to pollen, fungi, and animal dander (dandruff from animal hair, feathers or skin); bacterial and viral infections; and reactions to chemical tox-ins that are released by fungi.

(Adapted from Environmental Resource Guide – Air Quality for Grades 6-8 by permission of Air and Waste Management Association.)

Student Page E *Home Radon Exposure Survey*

1. Check geologic and soil maps of your area. Determine the type of bedrock and soil underneath your home.

   - What is the main type of bedrock in your area?
   - What types of soil are in your area?

2. What types of building materials are in your home?

3. Describe the foundation of your home.

4. Do you have a basement?
   - Does the basement floor have cracks?
   - Do your basement walls have cracks?
   - Is your basement sealed to keep moisture out?
   - Is your basement completely below ground?
   - Does the basement have ventilation?

5. Is your home drafty or tightly sealed with insulation?

6. Is there a place for air to circulate beneath your home?

7. Does your home have an exhaust fan? Where is it located? How often do you use it?

8. Do you use fans other than exhaust fans? What kind? Where are they located?

9. Do you air out your house for several hours or days from time to time?

10. About how many hours do you spend in your home every day?

11. In which room(s) do you spend most of your time at home?

12. What is the water source for your home?

    If you use well water, does the water flow through limestone or shale?

(Adapted from Environmental Resource Guide-Air Quality for Grades 6-8 by permission of Air and Waste Management Association.)

Managing Air Quality In Virignia

Script for the Virginia Air Pollution Power Point presentation

A script for use with the powerpoint slide show accompanying the CD in the 2005 Love-A-Tree kit.

Slide #1 **Virginia Air Pollution – Is the air we breathe safe? How do you know?** This presentation will show what potentially could be in the air we breathe, what is being done to minimize pollution, and how citizens can check what is going on in their area and help reduce air pollution themselves.

Slide #2 **Air Pollution.**

- Dust (sometimes called particulate matter or PM)
- Smog/Ozone (created from volatile organic compounds or VOC)
- Exhaust from fuel burning contains primarily carbon monoxide (CO), nitrogen oxides (NOx) and sulfur dioxide (SO2).
- Hazardous chemicals are those on the list of 188 hazardous air pollutants (HAPs) that EPA tracks

An air pollutant can be considered "anything in the air in quantities that are detrimental, whether from man made or natural activities."

What are some examples of natural air pollution? Forest fires, volcanoes, swamps and wind erosion.

Slide #3 **Dust** is mainly from smoke, airborne dirt, and wind erosion but can also include aerosol droplets. It is of concern because it has the capacity to enter the lungs and cause harm. It also reduces visibility. Particles smaller than 2.5 micrometers or microns are especially of concern because they are hard to control; they stay in the air for a long time; and may be the source of most lung damage. You would need an electron microscope to see a particle this small.

Slide #4 **Smog/Ozone** is formed from the reaction of NOx and VOC in the presence of sunlight (photochemical reaction). Car exhaust is the primary source of these pollutants. Virginia and EPA monitor the air for ozone and if levels are predicted to be high, an alert is issued (see Air Quality Index table below).

The **Air Quality Index** is a measurement of air quality that is calculated from ozone and fine particle pollution measurements over the past few hours. A higher AQI indicates a higher level of air pollution, and consequently, a greater potential for health problems.

Level	**Color**	Description
**	White	Air quality information is unavailable.
0-50	Green	Good air quality. Little or no health risk.
51-100	Yellow	Moderate air quality. People who are unusually sensitive to air pollution may be mildly affected.
101-150	Orange	Unhealthy for sensitive groups. These groups may experience health problems due to air pollution.
151-200	Red	Unhealthy. The general public may experience mild health effects. Sensitive groups may have more serious health problems.
201-300	Purple	Very unhealthy. Everyone is susceptible to more serious health problems.

Good ozone exists in the upper atmosphere and protects the earth from solar radiation. Bad ozone is found near the ground and affects the health of people, animals and plants.

Slide #5 **Pollution From Fuel Burning** comes from a wide variety of sources and can include a variety of chemicals. In addition to CO, NOx and SO2; smoke, VOC and HAPs can also be emitted. These pollutants cause many symptoms which, over time, can weaken people. They cause crop losses. And not only do these pollutants have detrimental effects in the air, they can settle into water and cause water pollution.

Slide #6 **Hazardous Air Pollutants** include those 188 chemicals that EPA considers to be a health risk and requires tracking for. They pose a variety of risks, from cancer to birth defects to irritation of the eyes, skin and lungs. Fore more information, check out http://www.epa.gov/ttn/atw/allabout.html

Slide #7 **How does Virginia's air rate?** Virginia monitors for CO, Ozone, SO2, NO2, PM10 and PM2.5 (and sometimes VOC). Sampling sites are located around Virginia, most near populated areas. Virginia is in attainment (meets the health standard) for everything but Ozone and PM2.5. The slide shows the ozone nonattainment areas and the monitor locations. These areas must reduce their levels of ozone until they meet the standards. This could take many years. EPA could withhold funding if the levels aren't reduced.

Slide #8 **National Ozone Nonattainment areas and severity –** While Virginia has some areas of non attainment (marginal and moderate) and some areas that might get such a designation if they don't do something now (the green EAC areas), other states, especially California, have worse air pollution. Less populated states have better air quality.

Slide #9 EPA has a website, called AIR Now, showing ozone or PM2.5 forecasts and monitored levels across the country or a region. Go to http://www.airnow.gov/ .

Slide #10 **Other factors influencing local pollution –** While states and local authorities can control the man-made pollution in their jurisdiction, they can't do much about pollution from other jurisdictions or from natural sources. This forest fire in Shenandoah Park was contributing to PM and visibility problems downwind as far away as the North Carolina border. Power plants in Ohio and West Virginia contribute to monitored pollution in Virginia. States and EPA must work together to solve these types of problems on a Regional basis.

Slide #11 **Regional haze** is being looked at very closely by EPA. Although this is an aesthetic consideration, it can also indicate other harmful pollutants in the air (small particles, acidic aerosols and ozone). It is believed that much of the haze is from large fuel burning equipment like those found at power plants. Recently EPA developed the Regional Haze Rule, the Clean Air Visibility Rule, and the Clean Air Interstate Rule to reduce haze and visibility problems across a larger region.

Slide #12 **Emissions Inventory –** Most of the significant air pollutant emitting sources are required to report their emissions every one to five years. This information is sent to EPA by the states that collect the information. EPA is able to take this data (so far only for the years 1996 and 1999) and manipulate it in a variety of graphical representations. This particular slide shows a summary of emissions data from facilities in Chesterfield County, VA. The large source is Chesterfield Power which has since installed pollution control equipment. To get your own report, go to www.epa.gov/air/data/geosel.html

Slide #13 **Regulations to Protect the Air –** A basic overview of how regulations developed over the years. The air was dirty, people were literally dying, and government stepped in to regulate the problem.

Slide #14 **Clean Air Act –** Basically, EPA was tasked with cleaning the air. In order to do that, they needed to know how dirty it was. They monitored the air for pollutants. They conducted research on the health effects of air pollutants. They gathered all that data together and came up with Air Quality Standards which are the

basis for the Clean Air Act (CAA). These standards are meant to protect the health of the more sensitive members of the population (the sick, elderly, and children). The states then had to propose ways in which they would implement rules so that the air quality in their state would not exceed these standards, or, if they did exceed the standards, how the state would reduce pollution to achieve those standards in a few years. In most cases, through the CAA, EPA was able to give the states plenty of guidance as to how to reduce pollution. Although states are free to be more stringent than EPA, they can't be less restrictive than those rules that EPA established.

The CAA requires new sources of pollution to determine the Best Available Control Technology (considering cost) to control pollutants emitted in relatively clean air (attainment areas). Older sources, (pre-1972 or so) do not need to add controls until they modify their equipment in some way or replace it with newer equipment (they do have to meet some less-stringent standards of emissions, though). Sources in nonattainment areas cannot increase emissions of those nonattainment pollutants at all and must actually emit less every time they modify their facility by adding controls already in place at other, similar facilities (cost not a consideration). Emitters of hazardous air pollutants must implement strict control strategies.

Some bugs that need to be worked out: Older sources quickly figured out that EPA's definition of "modification" had some room for interpretation and were able to continue to pollute even though they upgraded their equipment slightly over time. EPA is still working on this issue with incentives for voluntary installation of controls and programs such as the Clean Air Visibility Rule which requires the biggest of the older fuel burning units to consider Best Available Retrofit Technology.

Slide #15 **Virginia Air Pollution Regulations –** Virginia, as with most states, adopted the Clean Air Act regulations and incorporated them into their own. Virginia requires new and modified sources of air pollution to apply for a permit to construct and operate a pollution source. DEQ permitting staff makes sure the pollutants emitted will not violate any air quality standards and that proper controls are used. The compliance staff makes sure the source is adhering to their permit by conducting on-site inspections of each facility at least every three years (larger sources get inspected annually). Major sources (emitting over 100 tons of any criteria pollutants or over 10 tons of any HAP) must go through a public notice period. This informs the public of an opportunity to get information on the permit action and submit comments.

Slide #16 **What can you do to reduce air pollution? –** Anything that reduces energy consumption helps by lessening the work of power plants, thereby reducing their emissions. Use "environmentally friendly" paints or cleaners with fewer VOCs or HAPs. Recycle glass, aluminum and newspaper so energy isn't used to create these products from scratch. Reduce fuel combustion at home by not using a grill or fireplace unless necessary, use hand-powered tools rather than lawn mowers, weed trimmers and electric or gas-powered tools. Don't burn brush or garbage. Take public transportation or use a fuel efficient car and reduce your trips.

Don't forget to visit http://www.deq.virginia.gov and http://www.epa.gov for more information on air pollution.

Car or Bike? The Choice is Yours

A cost-benefit analysis lesson to complete after viewing EasyBreathers video, http://www.easybreathers.org

Related SOL Science: 6.2, 6.6, 6.9
Math: 6.6

Educator Background The goal of this activity is to explore choices and to learn about conserving and protecting natural resources. Students will explore how we use natural resources in our day-to-day lives, and identify what individual and societal choices people can make to manage our natural resources.

Each mode of transportation consumes energy at different rates. Shifting to more efficient transportation methods can significantly reduce energy consumption. By looking at natural resource supply and demand, students can better understand how our mobility choices affect future generations and the environment.

Learning Objectives Students will:

- understand the difference between renewable and nonrenewable energy resources;
- discuss environmental impacts of different modes of transportation;
- offer perspectives on the hidden costs of transportation;
- use assessments to help better understand how personal habits affect the environment;
- consider alternative ways to conserve energy and reduce air pollutants.

Procedure

- Watch the video "Easy Breathers."

- ***Activity 1. Background.***
  Divide students into working teams of no more than four.
  Have students read Unit Background from *Going Places, Making Choices.*
  Give teams time to answer the questions at the end of the section.
  Discuss the questions as a class.

- ***Activity 2. Personal Transportation Assessment.***
  Do most people do things out of habit, or because of need? In this activity, students will examine the transportation choices they make every day, and analyze the costs and benefits of their choices.

Personal Transportation Assessment. Make a list of all the places you go outside their homes in a typical week. Calculate the total number of miles traveled in a week. Calculate the percentage of miles using each mode of transportation.
(Note: This can also be done as a homework project to calculate actual history of miles traveled each week.)

Places You Go	*How do you get there? (family vehicle, bus, bike, walk, carpool, other)	A Round Trip Miles (How far is it one way? x 2)	B Number of Weekly Trips	A x B = Total Number of Miles
School				
Sports Practice				
Scouts or church-related organizations				
Music lessons				
Friend's house				
Job (babysitting, etc.)				
Mall or other shopping				
Entertainment (movies, games, concerts, etc.)				
Restaurants				
Other-list below ▪				
▪				
▪				
▪				
▪				
Total miles	**	**	**	

*If you rode in your family's vehicle and did not provide a ride to another young person, record as "family vehicle." If you provided a ride to a friend or meighbor or rode with someone else in their vehicle, record as "car pool."

Discussion

1. How many total miles did you walk?
   Calculate % of total miles
2. How many total miles did you ride your bike?
   Calculate %
3. How many total miles did you take the bus or metro?
   Calculate %
4. How many total miles did you take your family vehicle?
   Calculate %
5. How many total miles did you ride in a car pool?
   Calculate %
6. What % of total miles used renewable energy resources?
7. What % of total miles used nonrenewable energy resources?

8. Could you realistically use a more energy efficient method for getting to the same places? (For example, could you use the bus rather than drive a car to school? Could you walk or ride your bike to your friend's house rather than drive?)

▪ ***Activity 3. Walk, Run, Skate, Bike Assessment:*** Is your area walker/runner/skater/or biker friendly? In the previous activity, students calculated how many miles they traveled each week. This activity examines the safety of transportation using alternative and renewable energy sources.

Note: This activity can be done in two different ways. It can be a class project to be done outdoors as a group. This can also be assigned as homework project to be done in small groups in the students' neighborhoods.

Take a Walk Assessment.

Take a walk with a team member or as part of a larger group. As you walk, use this checklist to decide if your area is a safe and friendly place to walk. Choose a route you usually travel by car or bus, such as to school or a local store.

	Yes	**No**
1. What are the sidewalks/trails like?		
▪ Is there enough room to walk/ride a bike?		
▪ Are there sidewalks/trails the entire way?		
▪ Are the sidewalks/trails in good condition (no missing chunks, large cracks, etc.)?		
▪ Are the sidewalks/trails unobstructed (not blocked with poles, signs, pipes, etc)?		
▪ Are there enough sidewalks/trails to make the walk/bike ride safe?		
2. How reasonable is the traffic?		
▪ The traffic yielded to people crossing the street.		
▪ The traffic is light enough so that noise isn't a problem.		
▪ The traffic moves efficiently and safely down the street.		
3. Was it easy to cross the streets?		
▪ The road is narrow enough to make crossing safe.		
▪ The traffic signals give us enough time to cross.		
▪ Nothing (such as parked cars or trees) blocks our view of the crossing.		
4. Is the area fun and safe?		
▪ The streets are clean and free of litter.		
▪ Any dog or other animal messes are cleaned up.		
▪ Trees, plants, and other scenery are maintained.		
▪ Other users are non-threatening.		

	1 = Terrible	2 = Still not good	3 = Not bad, not good	4 = Good	5 = Very good
Location					
Overall conditions of the sidewalks					
Overall traffic conditions					
Overall road conditions					
Overall safety and fun conditions					
Total					
Overall score 15-20 Good 10-15 Could use help 5-10 Needs serious work 0-5 No support of alternate activities					

Discussion.

1. Why is it so easy/hard to walk in this area?
2. Why do you think walking is/isn't supported with more tax dollars and infrastructure?
3. Do you think other forms of transportation, such as buses, biking, and trains are well supported in this community? (If you were to give a grade, what would it be?)

▪ ***Activity 4. Pollution and Pollution Prevention.*** How much pollution and greenhouse gas do your activities add to the environment? How much could you prevent?

Generally, a 20 mpg car produces 0.04 pounds of carbon monoxide, 0.0045 pounds of nitrogen oxides, and 0.98 pounds of carbon dioxide for each mile driven.

Use the table you created for Activity 1 to determine how many pounds of each pollutant each weekly activity produces.

Places You Go	Total Number of Miles	Pounds of carbon monoxide (CO)	Pounds of nitrogen oxide (NOx)	Pounds of carbon dioxide (CO2)
School				
Sports Practice				
Scouts or church-related organizations				
Music lessons				
Friend's house				
Job (babysitting, etc.)				
Mall or other shopping				
Entertainment (movies, games, concerts, etc.)				
Restaurants				
Other-list below ▪ ▪ ▪ ▪ ▪				
Total miles		**	**	**
Total pounds	**			

Discussion.

1. Using the above data, calculate how many total pounds of CO, NOx, and CO2 are produced per year.
2. How much could you save by walking or riding your bike?

- ***Activity 5. Personal Cost/Benefit Analysis. Bike or Drive: The Choice is Yours.***

You finally turned 16-and-three months and have just received your driver's license. On occasion, your parents have agreed to allow you to use their car (a medium-sized sedan) on the weekends. However, you have to pay for your own gas and give them $0.37/mile for wear-and-tear, insurance, etc. You got a new bike for your last birthday and have been using it for most of your weekend trips.

This weekend you and your friends have made plans to see an afternoon matinée. The movie theater is less than five miles from your house. Your friends either have rides or are riding their bikes to the theater.

Discussion.

1. How would you decide whether to borrow the car or ride your bike?
2. What factors will you consider?
3. What is your decision?

4. If one of your friends didn't have a ride, would your decision change? Why or why not?
5. Do you think you would use transportation other than cars if good options existed? How would things have to change for you to use these other options?

Extension.

Present and future assessment.

Describe your environment. Start with the area. Do you live next to the ocean or other large body of water? Are there mountains nearby? Is the land flat or hilly? Describe the climate. Is it a warm, cool, or temperate climate? Are there many days when it is hard to see or breathe? Do you live in a city, the suburbs, or the country? Does the area have much industry? Is it agricultural? Are there lots of abandoned buildings and stores or lots of construction?

Now project what the same environment will look like in ten years if things remain pretty much the same. What will it look like in 50 years? Make a table of your predictions listing all the characteristics and the changes.

Look at the list of characteristics of your environment. Is there one characteristic that could be changed that would make your environment a better place to live in 10 years or in 50 years? What needs to happen for that change to occur?

This lesson is about making environmentally sound choices, adapted from "Going Places, Making Choices," a curriculum by the National 4-H Council and American Honda Motor Company, Inc. This curriculum focuses on raising the awareness of high school age youth about transportation, personal mobility choices now and in the future, and how those choices impact the environment.
http://4hgpmc.com/teachers/product.asp?productid=65

Other resources.

http://www.fueleconomy.gov – *An EPA website that provides gas mileage information and gas prices.*

http://www.ouraaa.com/news/library/drivingcost/index.html – *Driving Costs Index by AAA shows how some mileage rates can be calculated.*

http://www.motherearthnews.com/Alternative_Energy/2005_October_and_November/making_wiser_transportation_choices *A website for making wiser transportation choices.*

http://www.ecocitycleveland.org/transportation/bicycles/bikes.html – *A bike-friendly website for healthy cities.*

http://www.times-up.org/ – *TIME'S UP! is a New York City-based not-for-profit direct-action environmental group that uses events and educational programs to promote a more sustainable, less toxic city.*